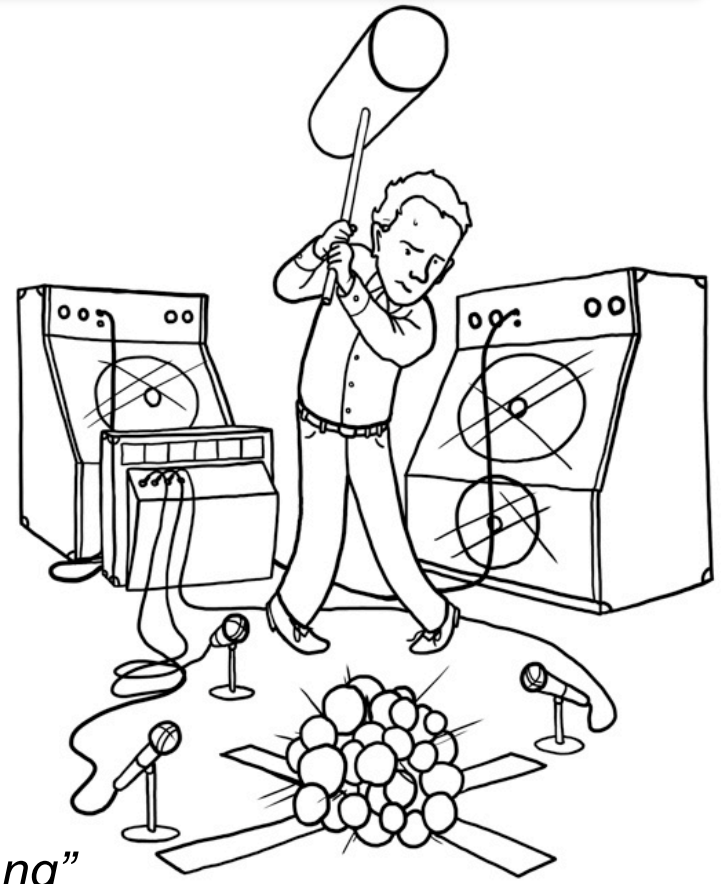
Status and Prospects in Heavy Flavor Probes

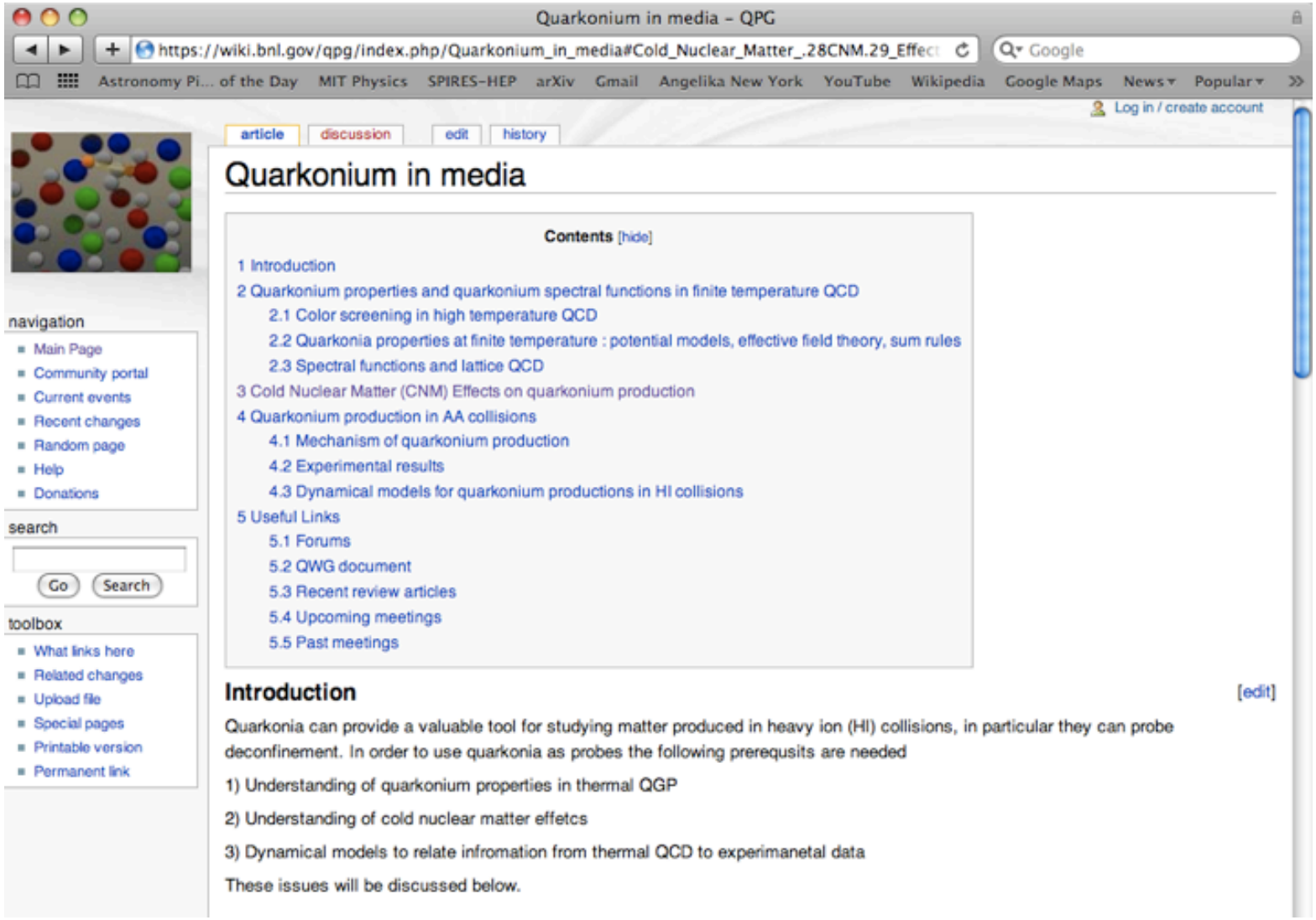
Ágnes Mócsy
Pratt Institute, Brooklyn, NY
Pratt



"The Sound of the Little Bang"

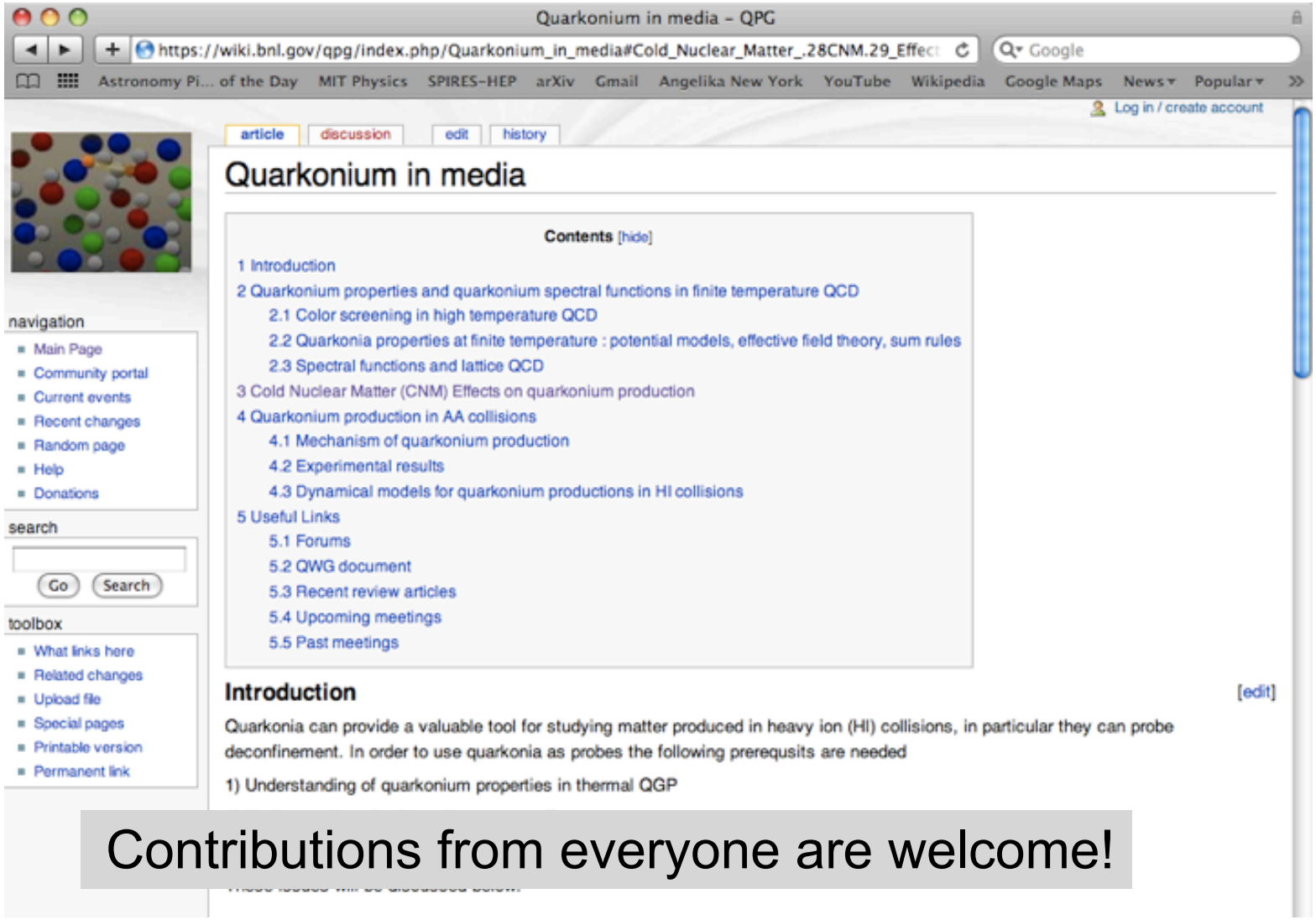
Illustration by Alex Doig (Pratt Institute)

Heavy flavor / Quarkonium Wiki



https://wiki.bnl.gov/qpg/index.php/Quarkonia

Heavy flavor / Quarkonium Wiki



Contributions from everyone are welcome!

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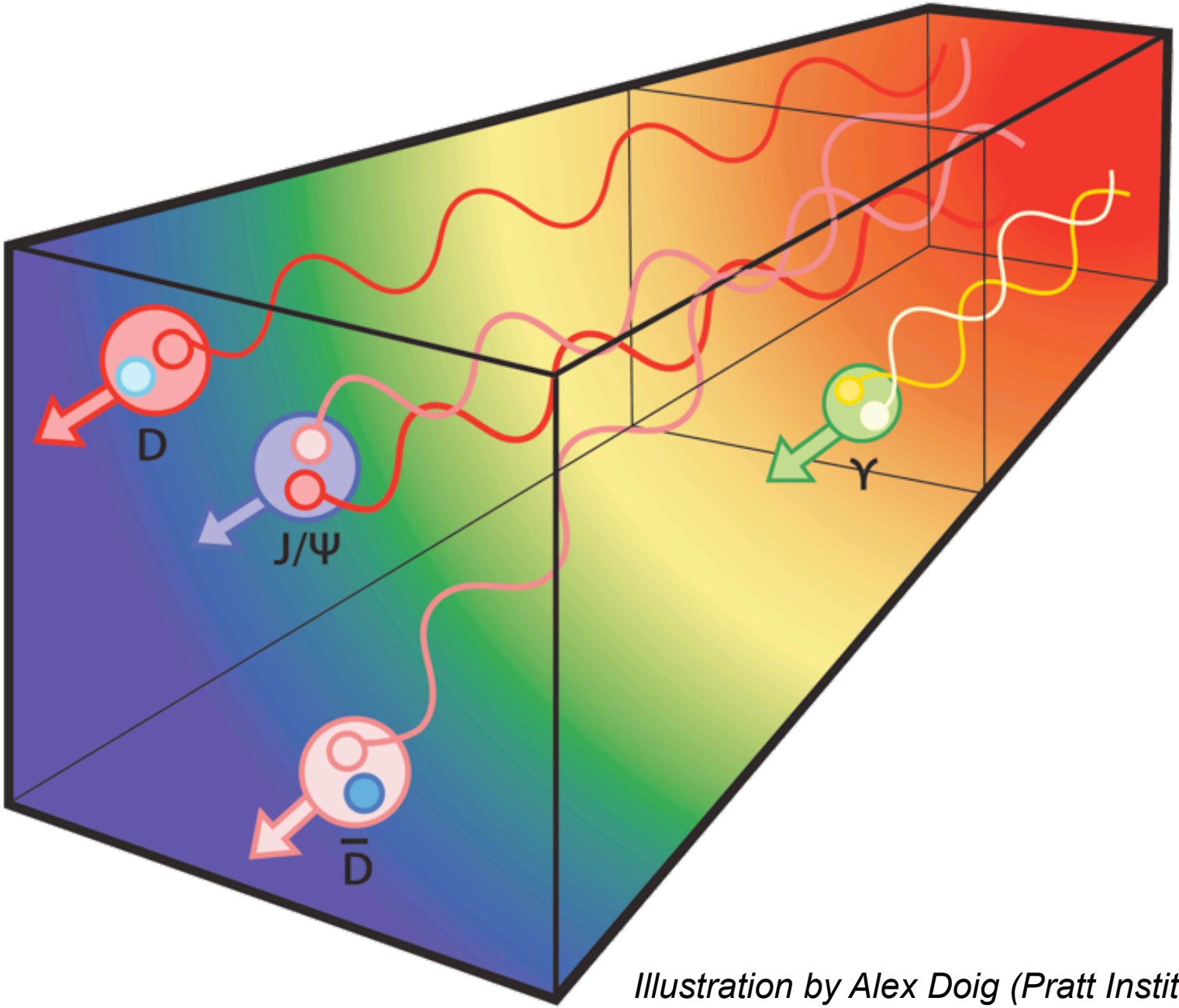

Illustration by Alex Doig (Pratt Institute)

The Quarkonium Puzzle

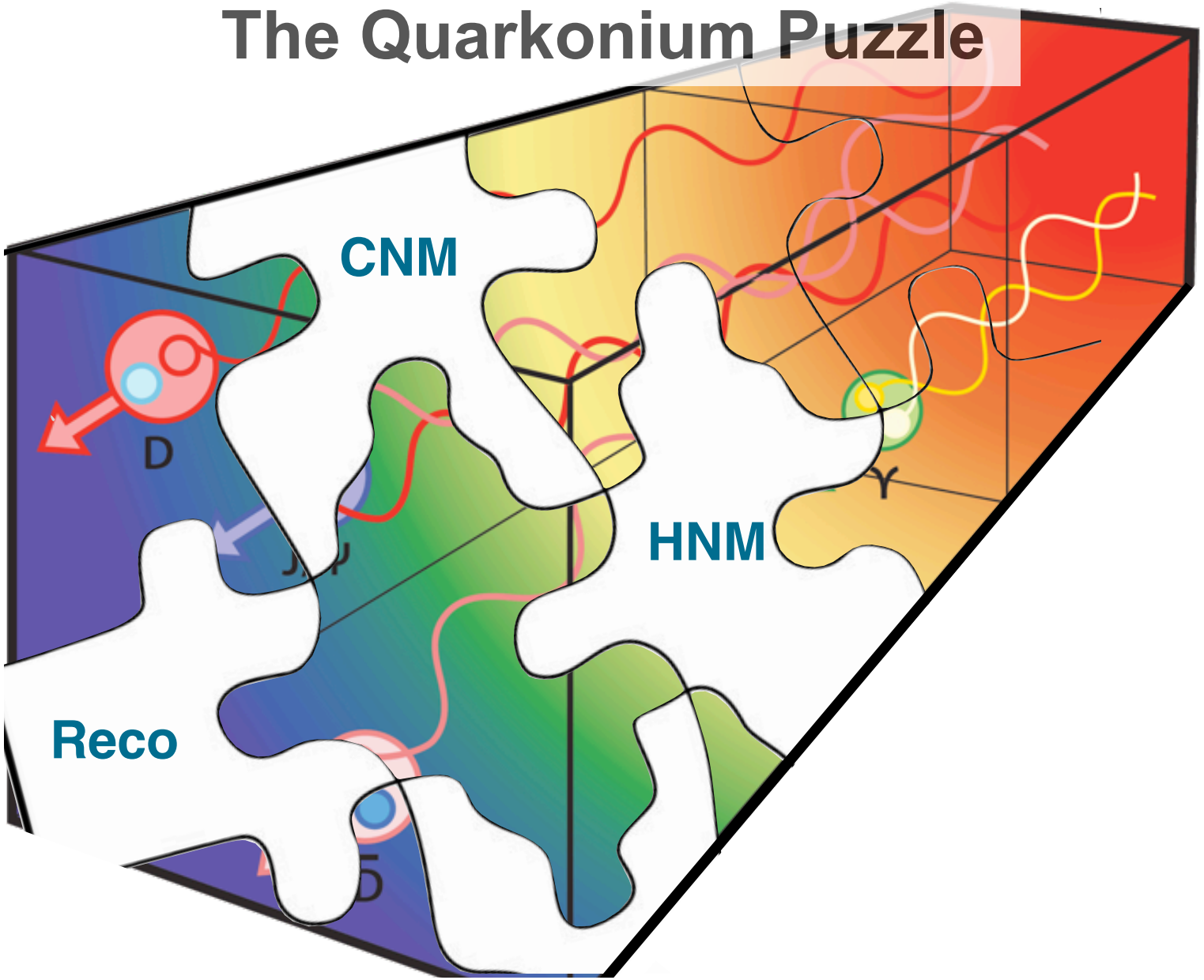

Illustration by Alex Doig (Pratt Institute)

Cold Nuclear Matter Effects

(Still is) A complicated problem

Talks by Ramona Vogt, Tony Frawley, Alex Linden-Levy, Jamie Nagle

Where do we stand ?

"We are revisiting all the issues we thought were resolved 10 years ago"

Ramona Vogt
(Jamie Nagle)

Where do we stand ?

"We are revisiting all the issues we thought were resolved 10 years ago"

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Energy dependence of the absorption cross section
paper by Gavin and Vogt 2000

The problem:

The heavy ion J/ψ data alone have not taught us as much as we would like, because of serious uncertainties caused by:

1) Poorly known initial state effects at RHIC:
- Break up cross section for collisions with nucleons.
- Shadowing.
- Other effects? Initial state energy loss?

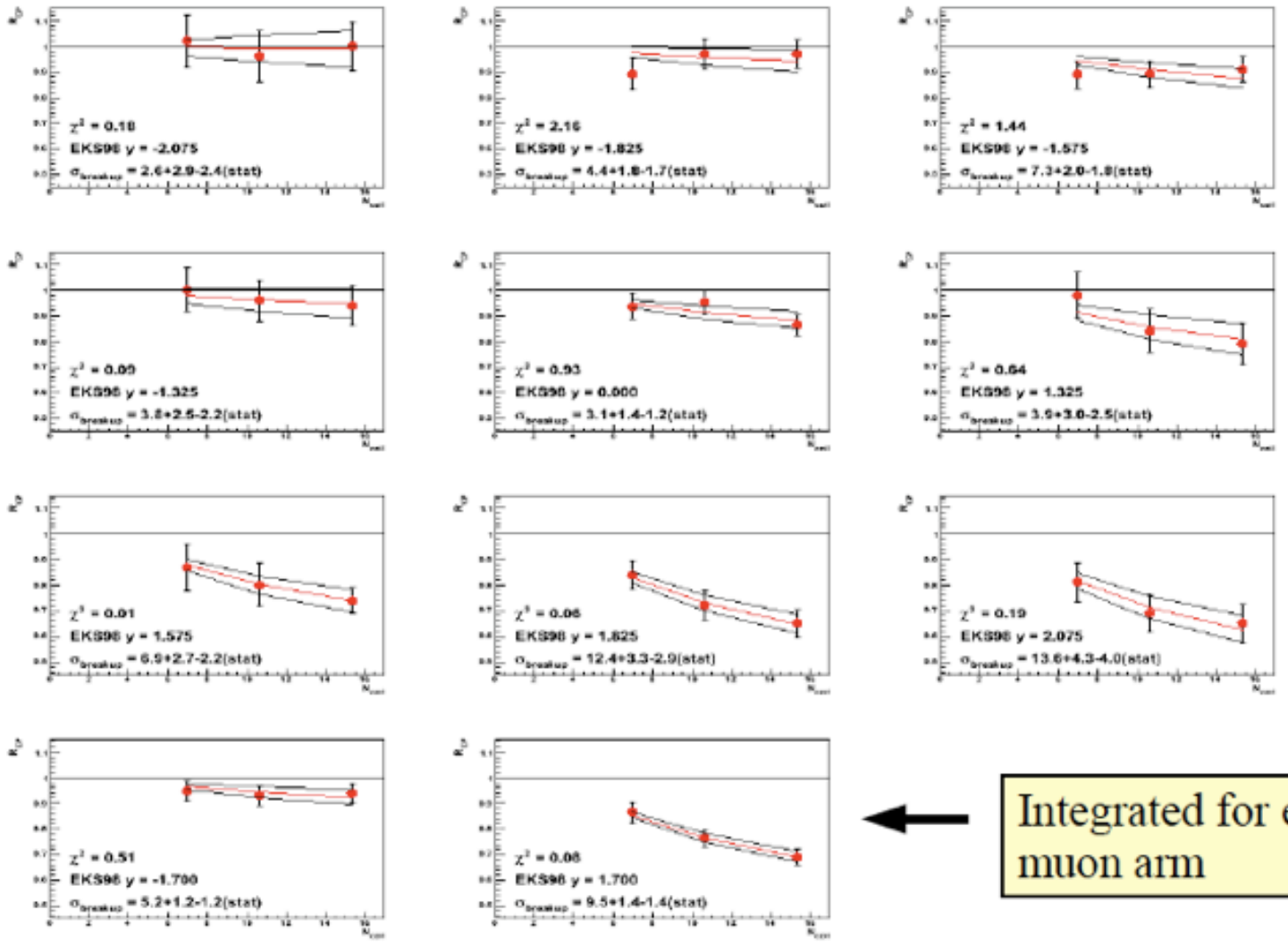
2) Poorly known open charm production cross sections.

Thus the trade-off between coalescence and destruction is difficult to illuminate experimentally.

To try to make inroads on 1), we start from the most recent d+Au data set:
– **Run 8 d+Au**
and try to understand what the Au+Au R_{AA} would look like without hot nuclear matter effects.

Talk by T Frawley

Fits to d+Au R_{CP} – example for EKS98



Integrated for each muon arm

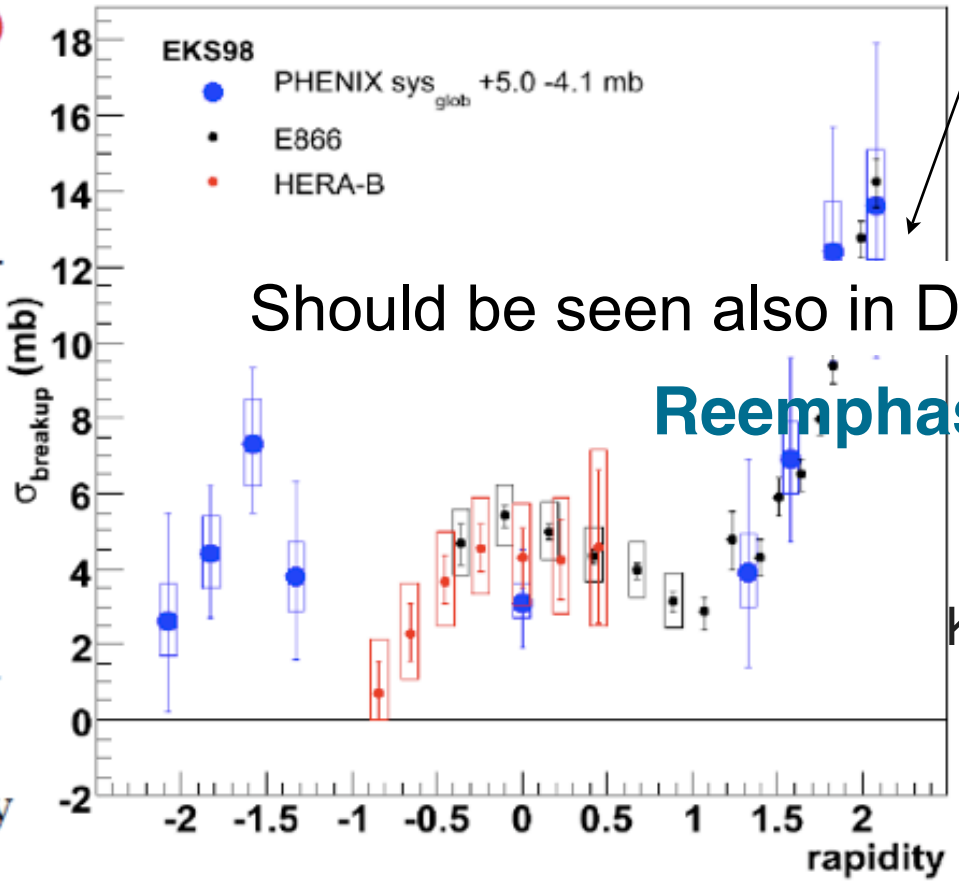
Talk by T Frawley

Comparison with lower energy data – EKS98 fits

Lourenco, Vogt and Woehri (JHEP 02 (2009) 014) published the effective breakup cross section vs y from fits to E866 and HERA-B data.

Our results from 200 GeV are shown here compared with their results, both for the EKS98 case.

For **y > 1.2** the 200 GeV data follow the trend observed at lower energy remarkably closely!



Initial energy loss?!

Should be seen also in Drell-Yan

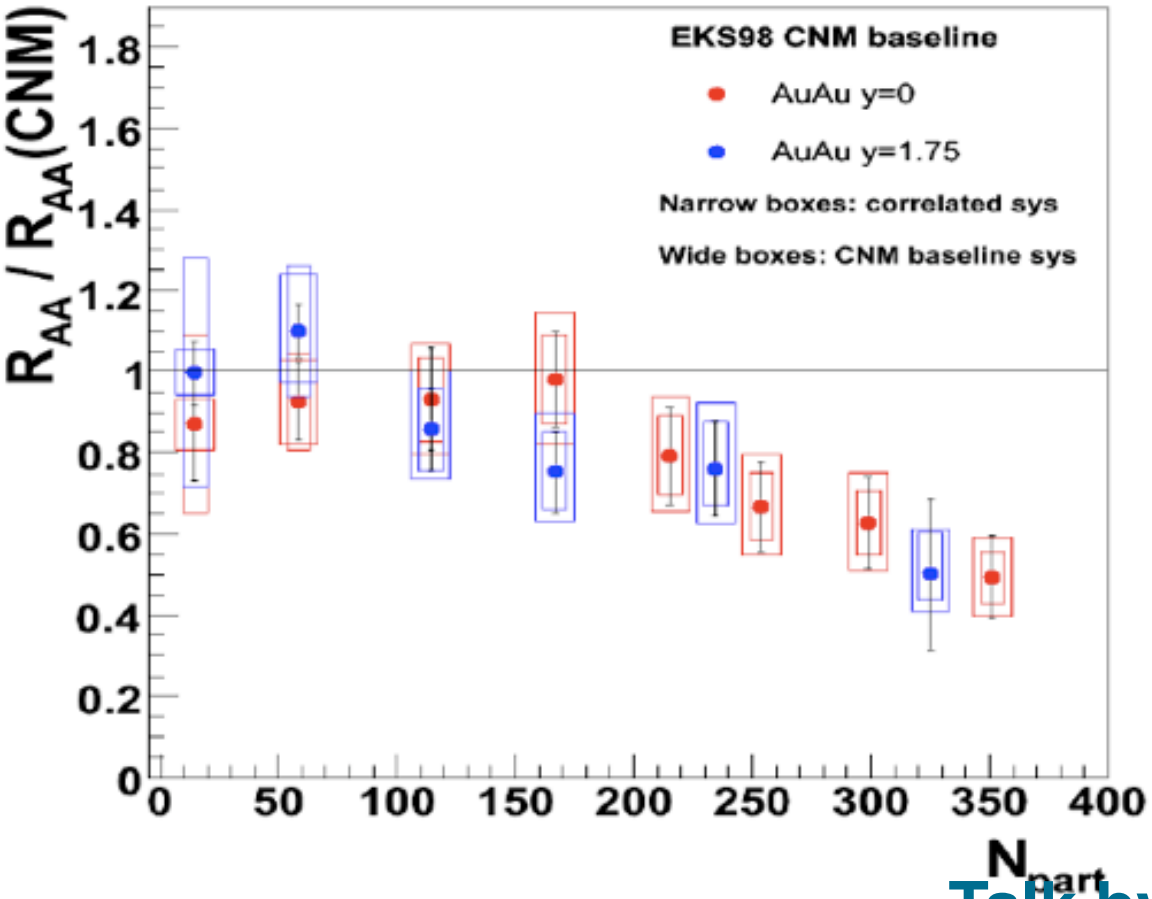
Reemphasized by J. Nagle

check out Kopeliovics

Talk by T Frawley

Results for Au+Au for the EKS98 case

The suppression beyond CNM effects is found to be similar at y=0 and at y=1.7. There is essentially **no** dependence on the shadowing model used to parameterize the d+Au R_{CP}.



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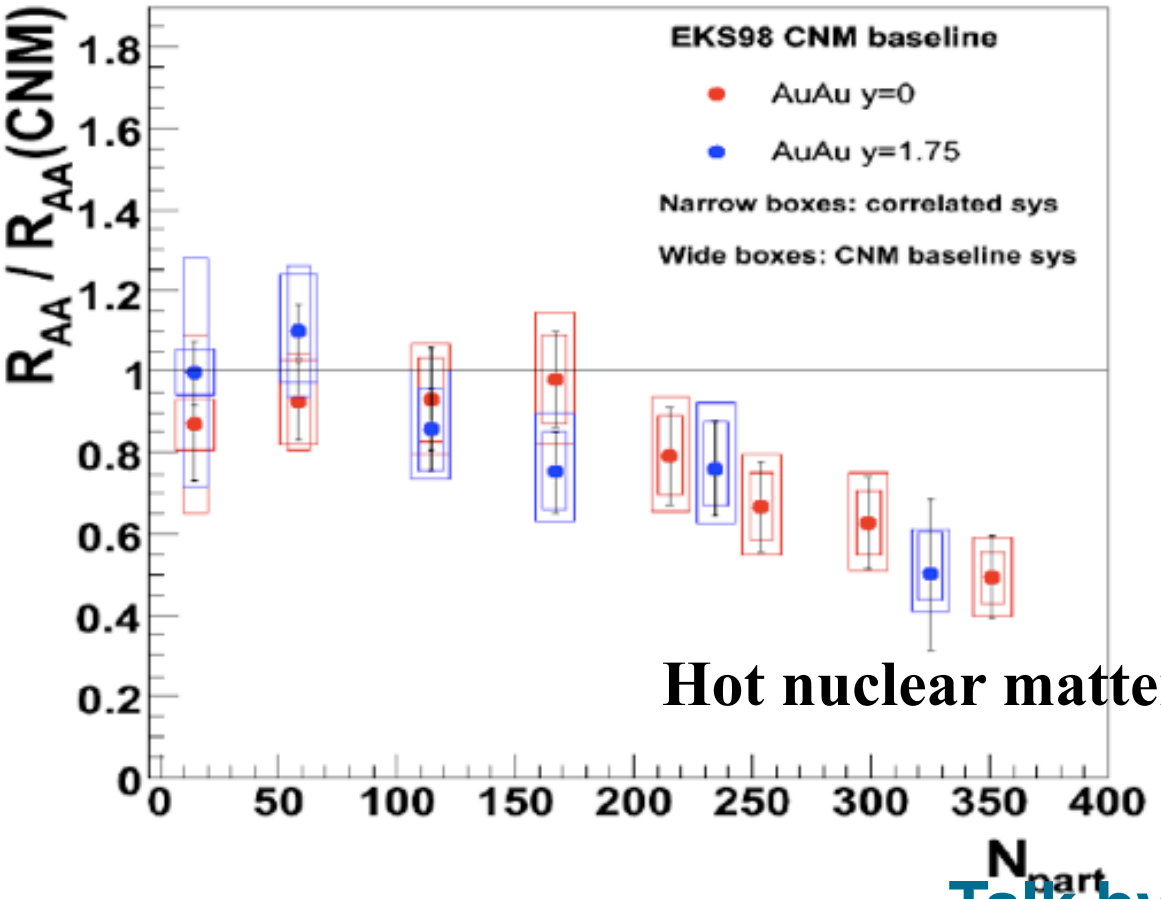
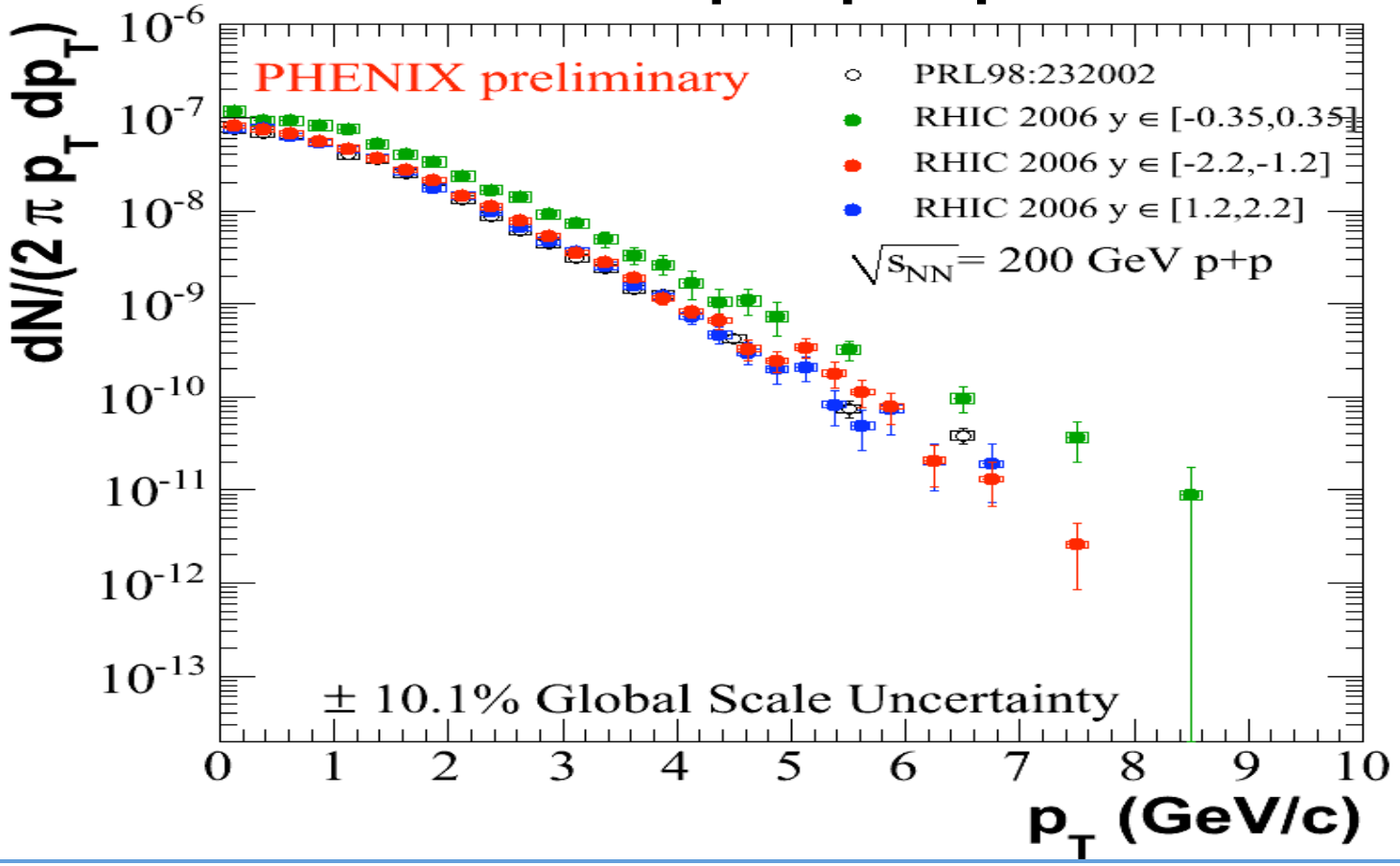


Hot nuclear matter effects

Talk by T Frawley

RHIC 2006 p+p spectra



- ~3X increase in statistics ~2x in systematic over publication [PRL98:232002].
- Powerful data set to test production models.

Talk by A. Linden Levy

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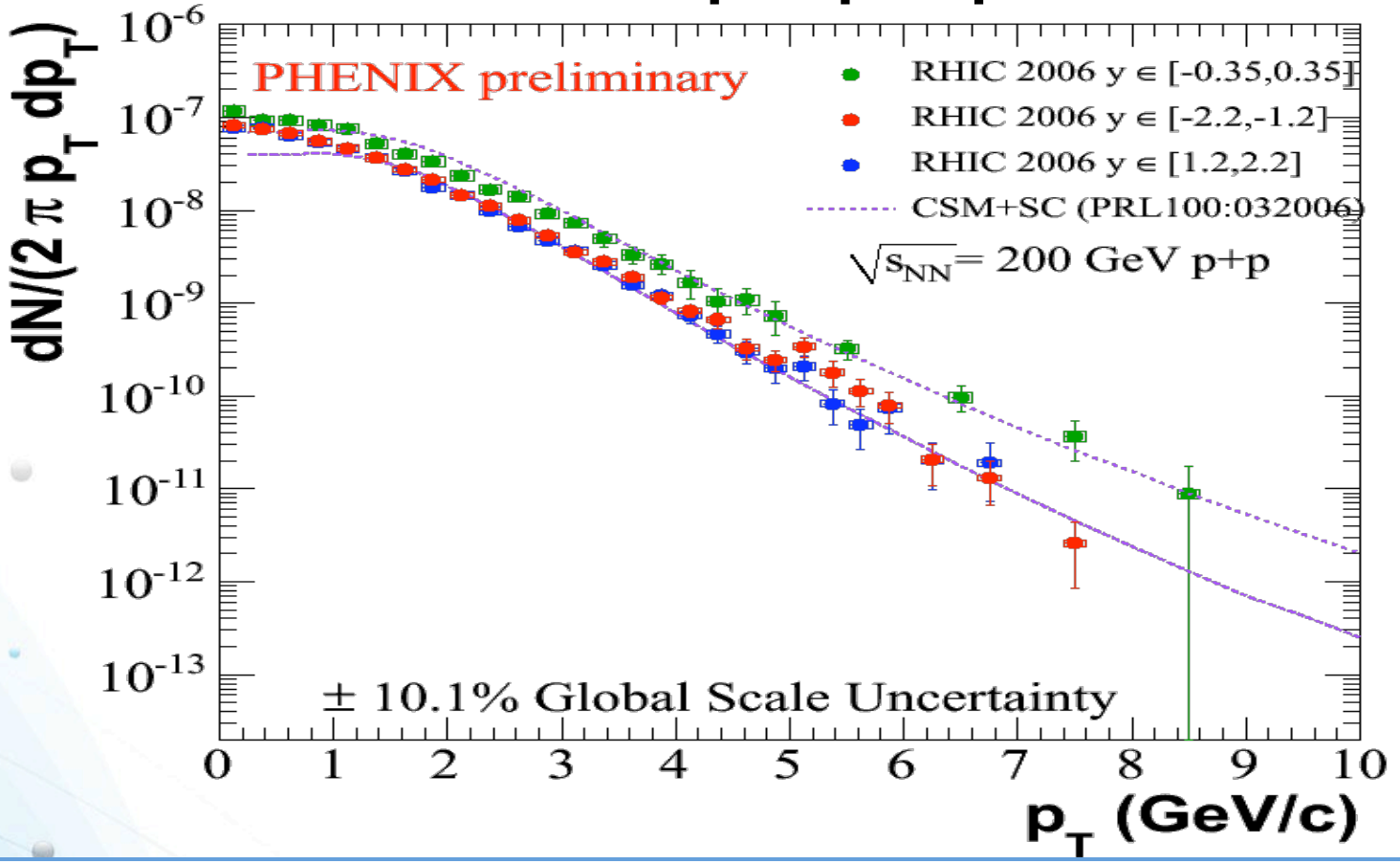

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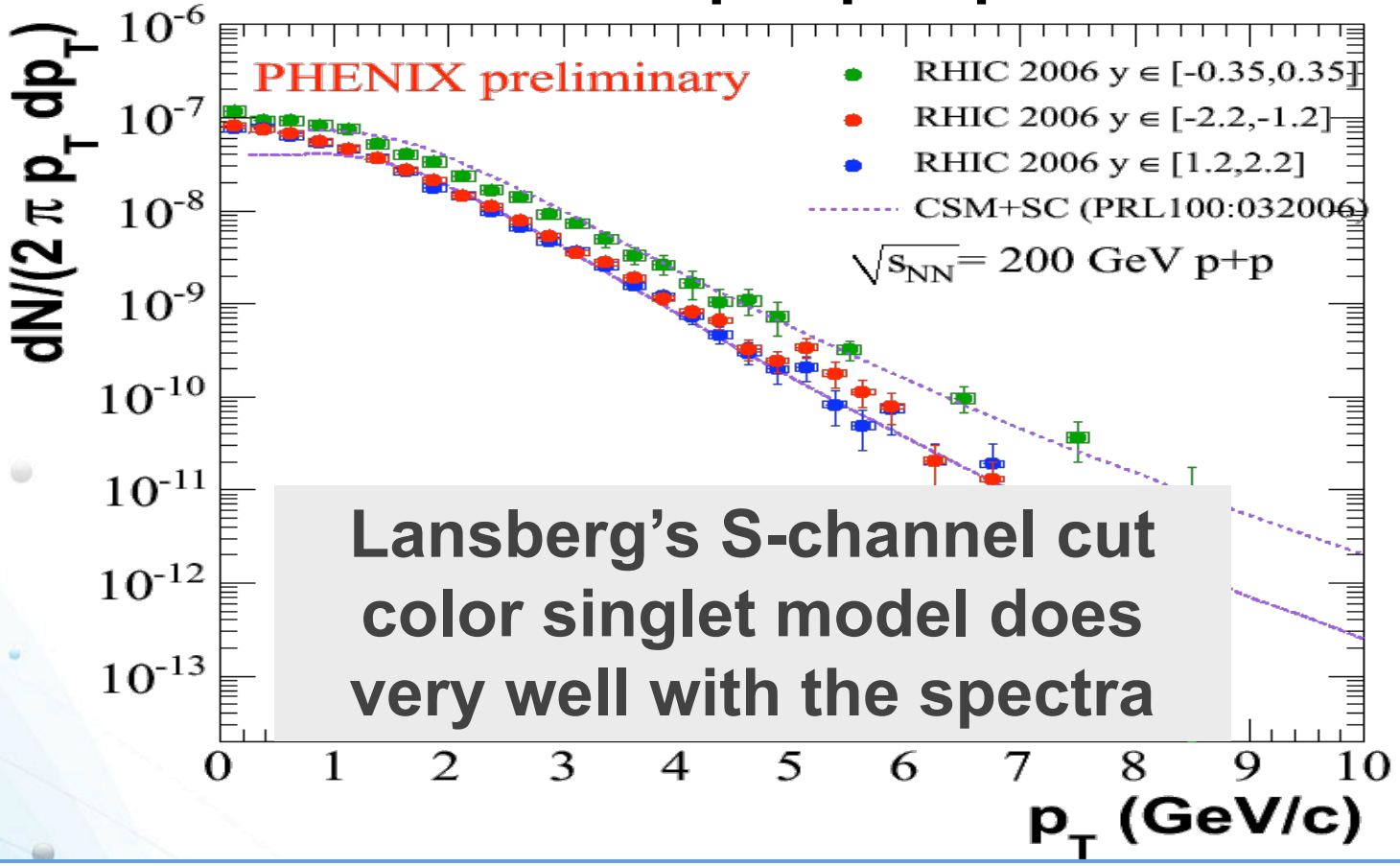

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- Powerful data set to test production models.

Talk by A. Linden Levy

Hot Nuclear Matter Effects

What are the in-medium quarkonium properties?

When does the Jpsi melt?

Is there a Jpsi peak in the spectral function?

What is the heavy quark potential?

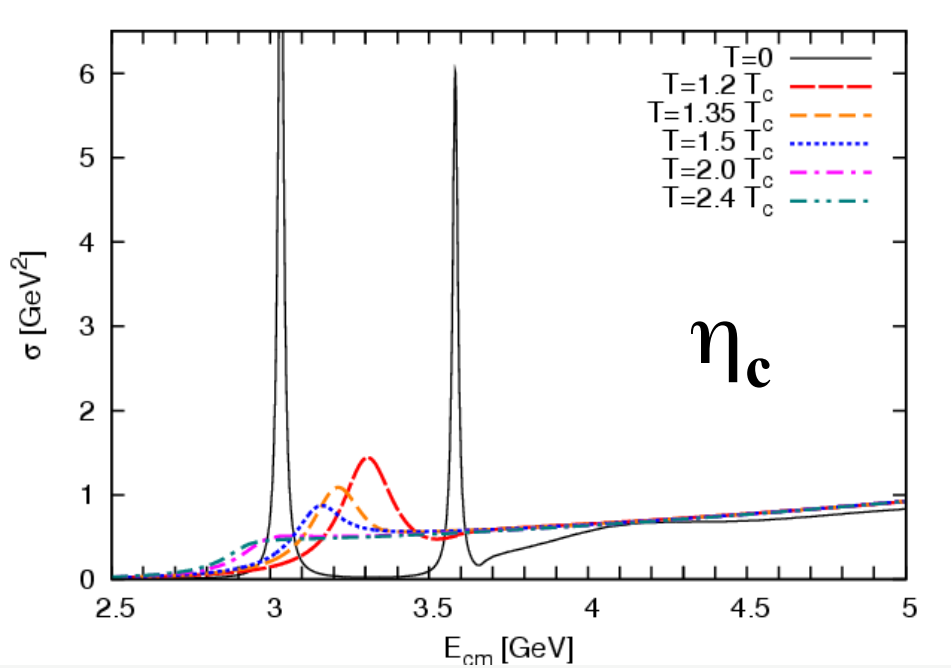
Potential model approach for quarkonia at finite temperature

Spectral function calculations using some lattice-based potentials

Talks by Ralf Rapp, Felix Riek, Agnes Mocsy

2.4.2 Example from "Extended T-Matrix

S-Wave Spectral Function

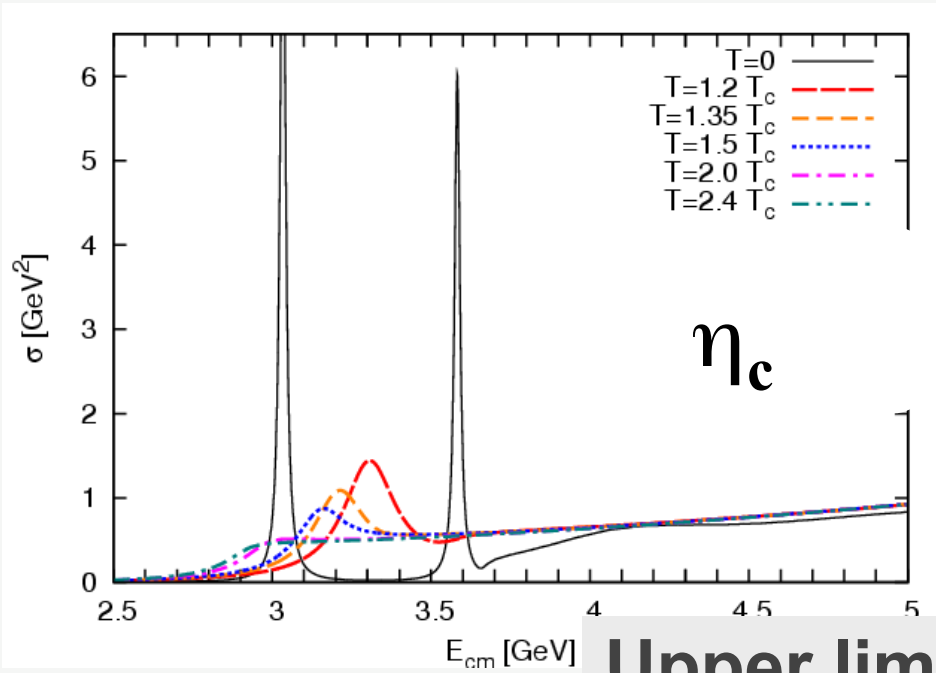


- $c\bar{c}$ propagator with Γ_c = 100 MeV:
- S-wave "melting" $T_{diss} \approx 1.5\text{-}2\ T_c$
- correlator ratio temperature-stable

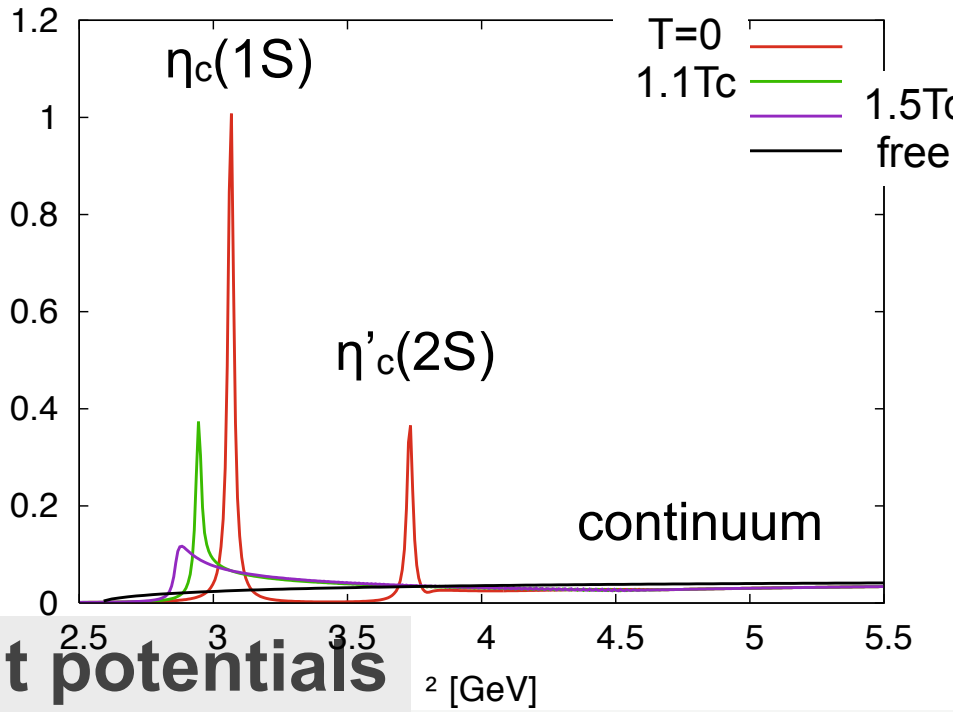
Rapp, Riek

2.4.2 Example from "Extended T-Matrix

S-Wave Spectral Function



Green's function calculation



Upper limit potentials

- **cc** propagator with Γ_c= 100 MeV:
- S-wave "melting" $T_{diss} \approx 1.5\text{-}2\ T_c$
- correlator ratio temperature-stable

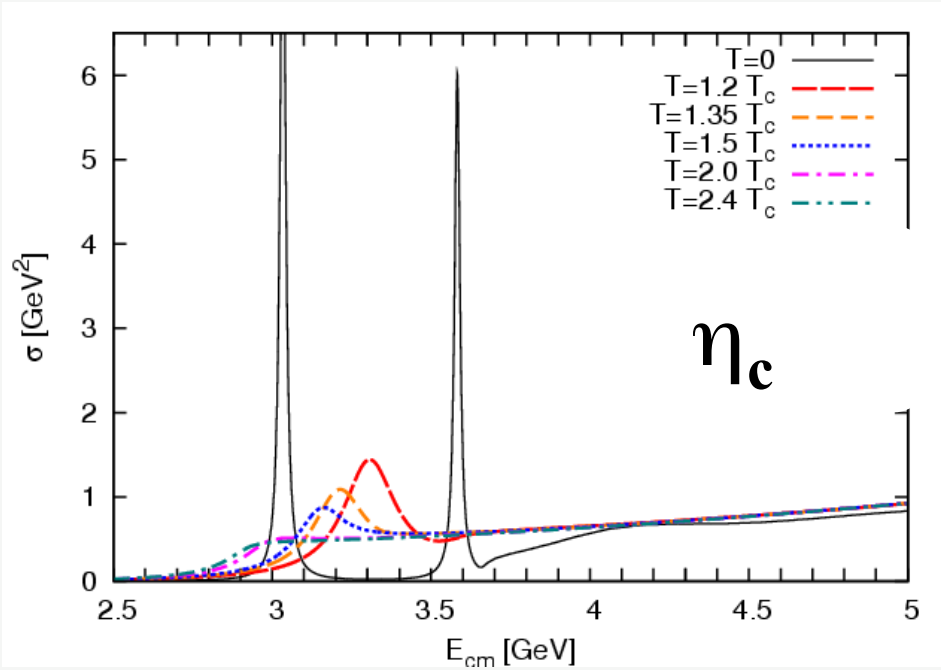
Rapp, Riek

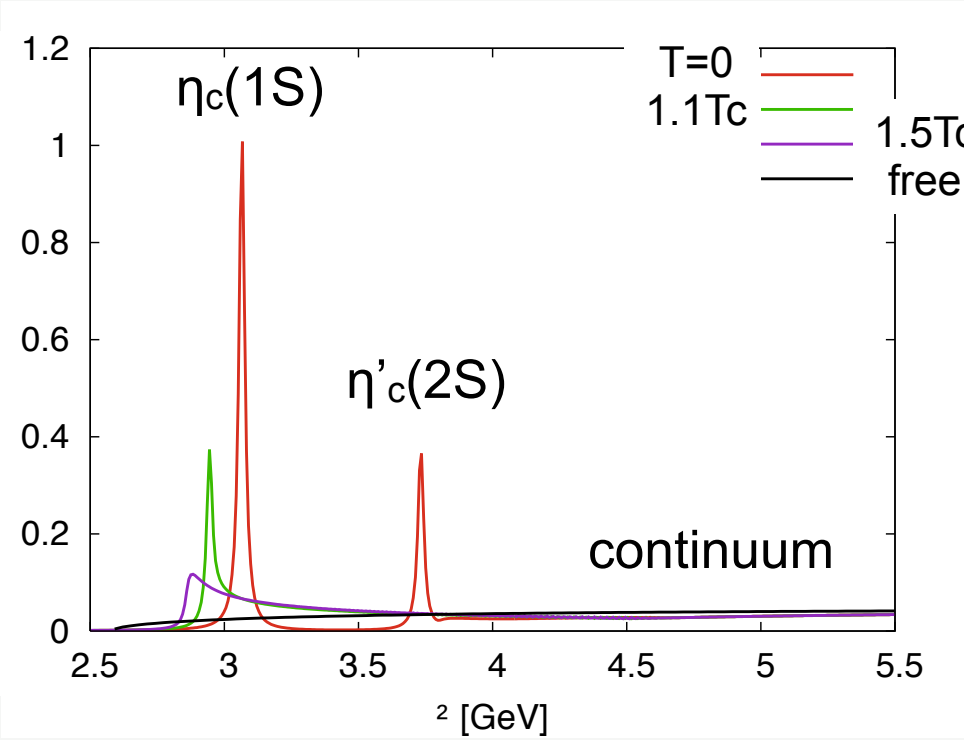
- Γ_c= 13 MeV
- $T_{diss} \lessapprox 1.2\ T_c$
- correlator ratio agrees to 2%

Mocsy, Petreczky

Do We Agree or Disagree?

S-Wave Spectral Function





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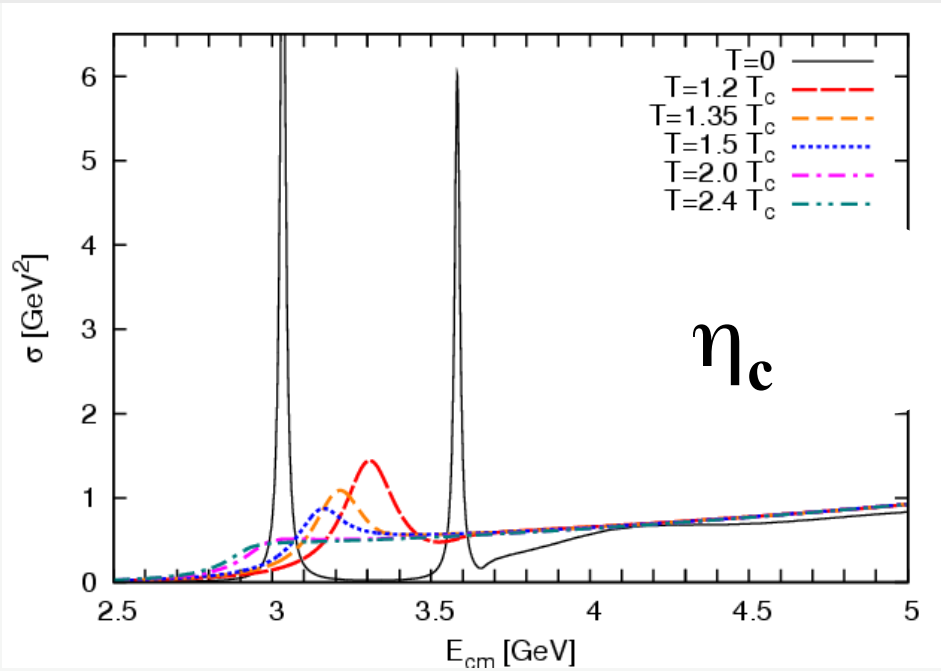
Rapp, Riek

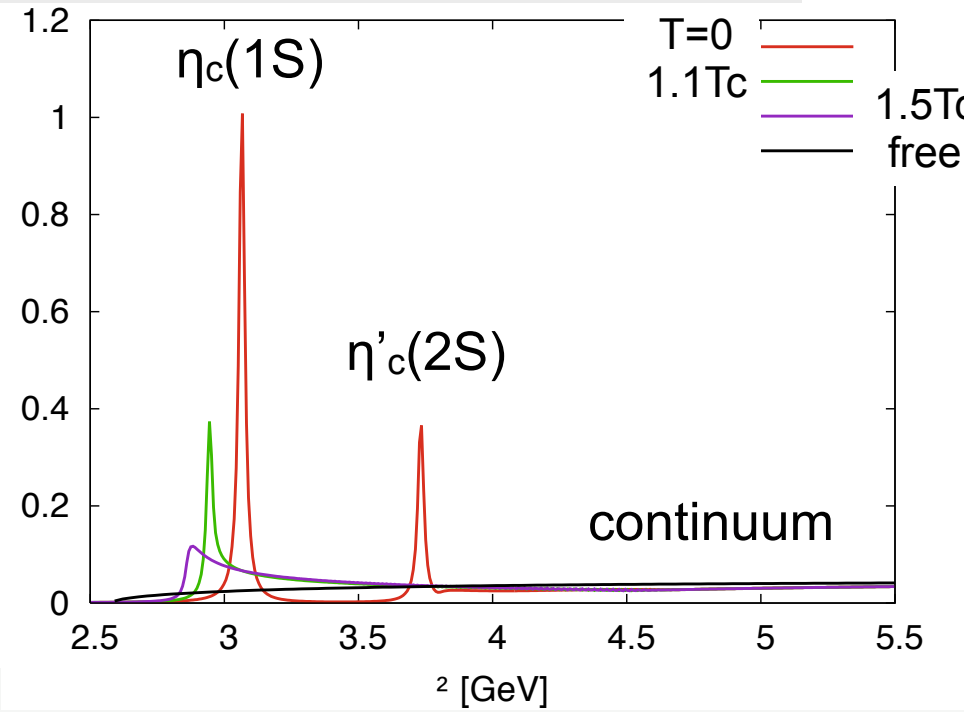
- **Γ_c= 13 MeV**
- **$T_{diss} \lessapprox 1.2\ T_c$**
- threshold enhancement
- correlator ratio agrees to 2%

Mocsy, Petreczky

Do We Agree or Disagree?

My answer: **Yes, we agree**. Please have a careful look.





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- correlator ratio temperature-stable

Rapp, Riek

- **Γ_c= 13 MeV**
- **$T_{diss} <\approx 1.2\ T_c$**
- threshold enhancement
- correlator ratio agrees to 2%

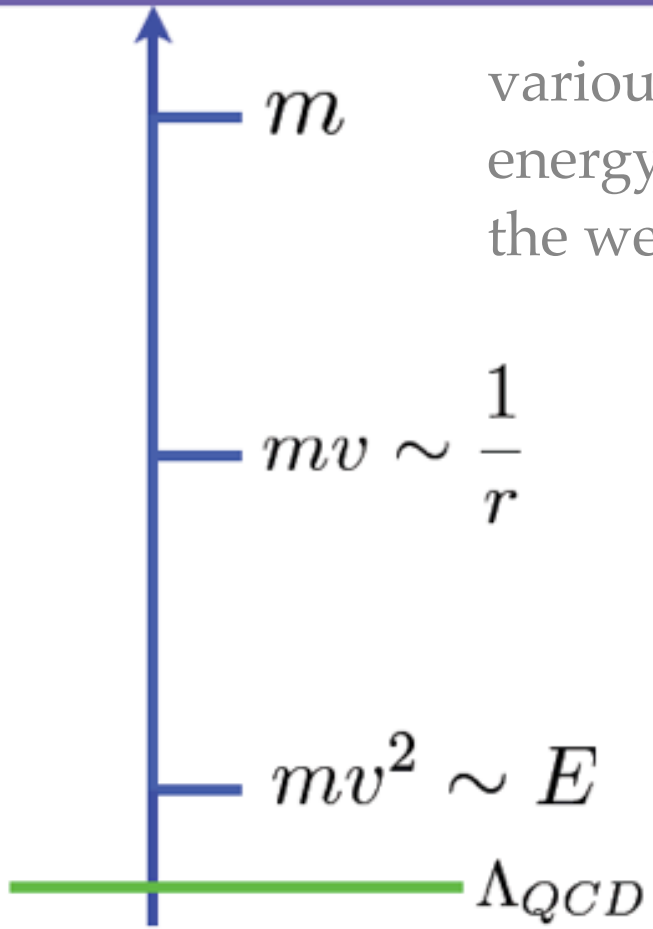
Mocsy, Petreczky

The EFT approach for quarkonia

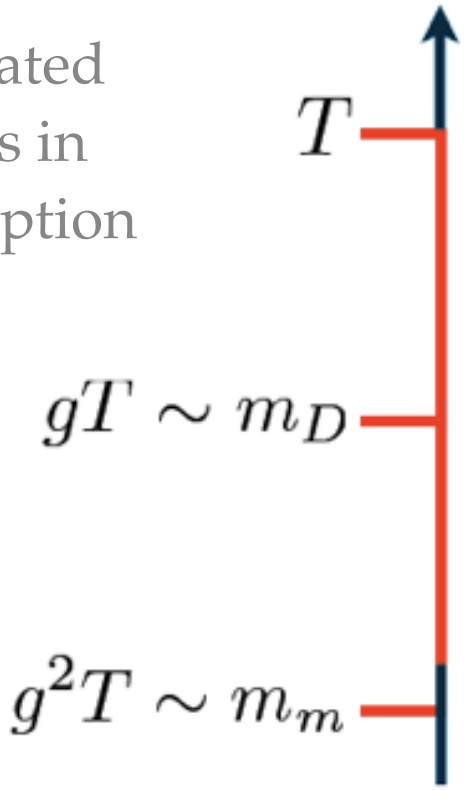
Systematic, non model-based
QCD approach to the potential

Talks by Jacopo Ghiglieri, Andrea Beraudo

Scales of the problem



various sufficiently separated energy/momentum scales in the weak coupling assumption

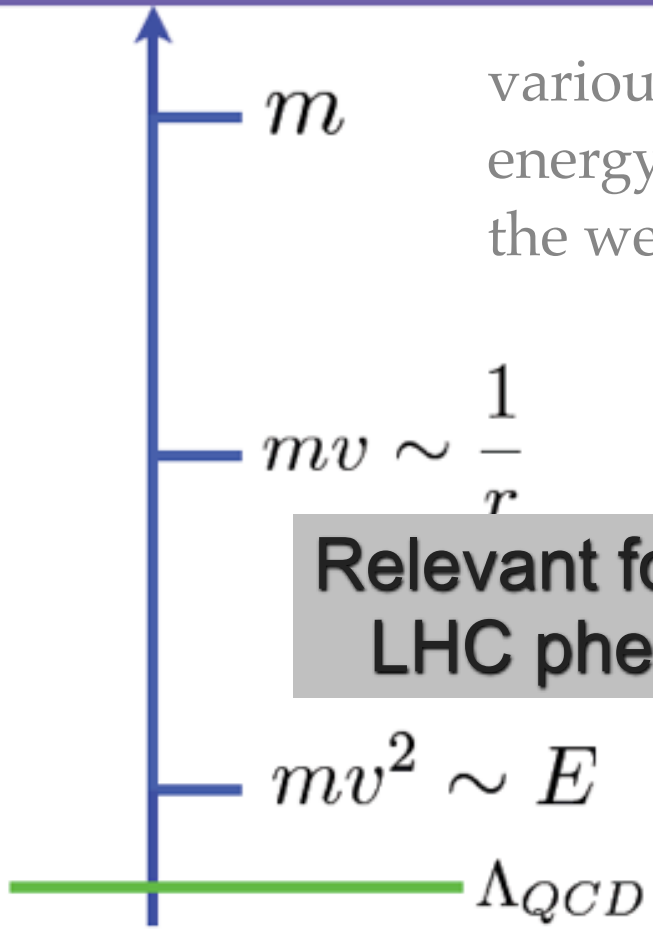


- Here we illustrate the intermediate case
  $m \gg 1/r \gg T \gg m_D \gg E$

Brambilla JG Petreczky Vairo 2008

Talk by J. Ghlieri

Scales of the problem



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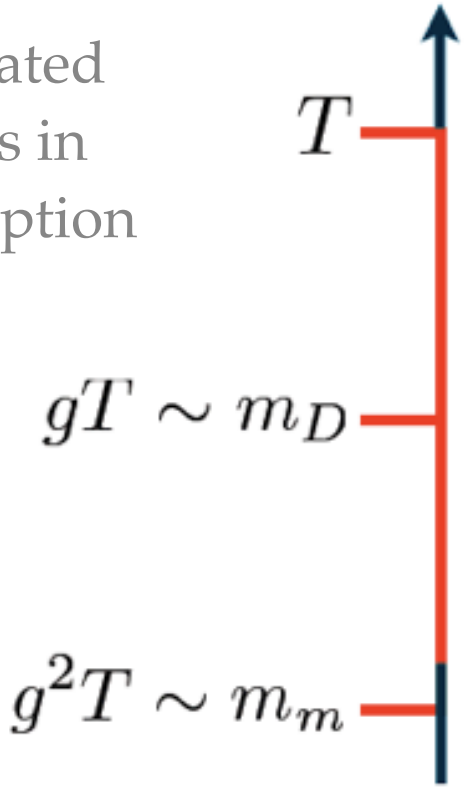

Relevant for the Upsilon, LHC phenomenology

- Here we illustrate the intermediate case
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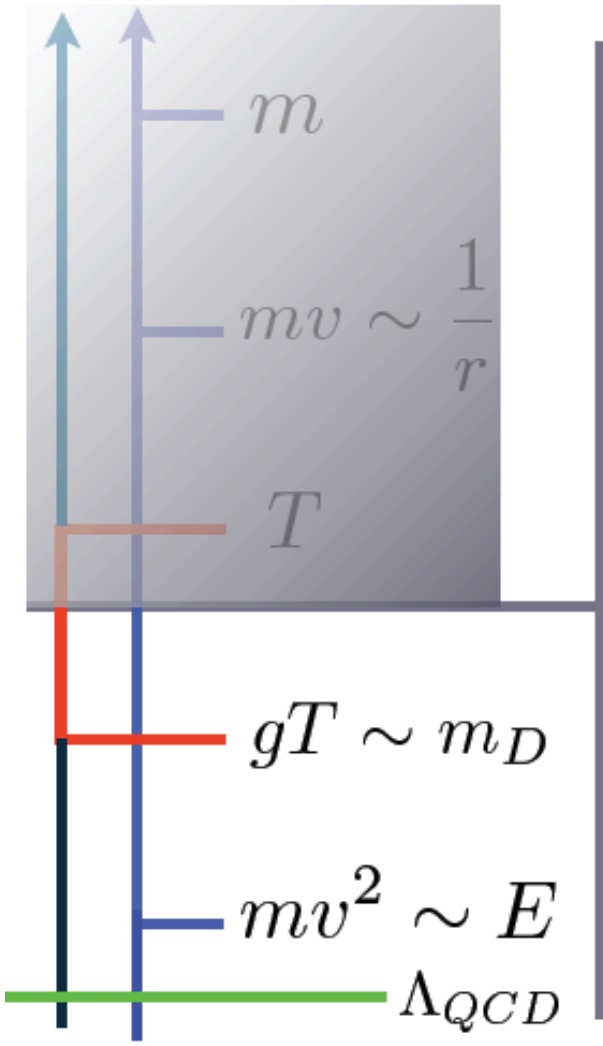
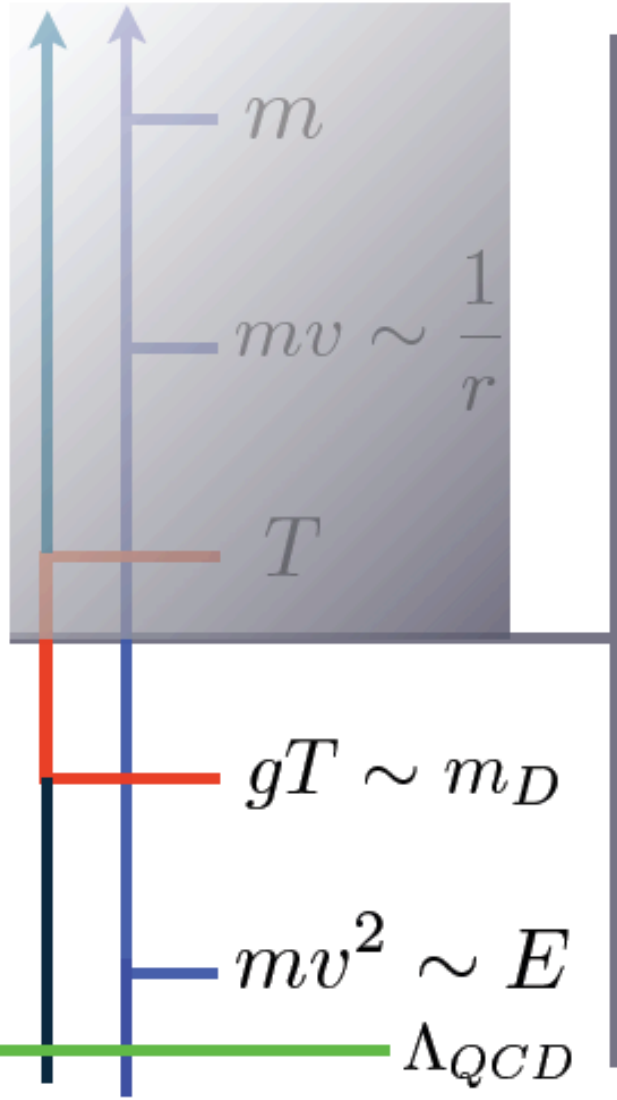


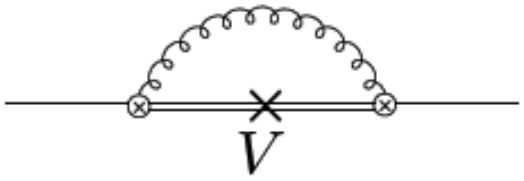
The temperature

- First thermal corrections to the potential (power law)
- Corrections appear as loops in the effective theory
- Real and imaginary parts, contributing to energy and decay width observables

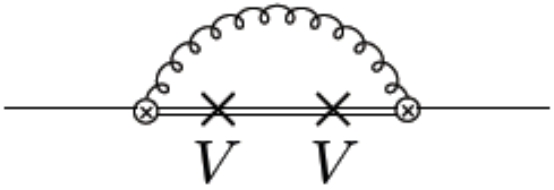
Talk by J. Ghlieri

Imaginary part can be as important as the real part





$$\mathrm{Re}\ \delta V_s(r) = \frac{\pi}{9} N_c C_F \alpha_s^2 r T^2 \qquad \sim g^2 r^2 T^3 \times \frac{V}{T}$$



$$\mathrm{Im}\ \delta V_s(r) = -\frac{N_c^2 C_F}{6} \alpha_s^3 T \qquad \sim g^2 r^2 T^3 \times \left(\frac{V}{T}\right)^2$$

- The imaginary part correspond to singlet-to-octet thermal breakup

Talk by J. Ghiglieri

In-medium heavy-quark spectral function: a path-integral approach

Andrea Beraudo

University of Torino and *CERN-Th.Div. (Centro-Fermi fellowship)*

BNL, 14^{th} – 18^{th} December 2009

Work in progress in collaboration with J.P. Blaizot (CEA-Saclay), G. Garberoglio and P. Faccioli (University of Trento)

Nucl. Phys. A 830, 319C-322C (2009)

Talk by A. Beraudo

This method will be really handy when we have to solve the EFT

In-medium heavy-quark spectral function: a path-integral approach

Andrea Beraudo

Our goal

We wish to perform a study resulting

- numerically less expensive then lattice calculations (hence allowing a more robust reconstruction of the spectral function);
- capable to get a deeper physical insight on the processes involved.

Talk by A. Beraudo

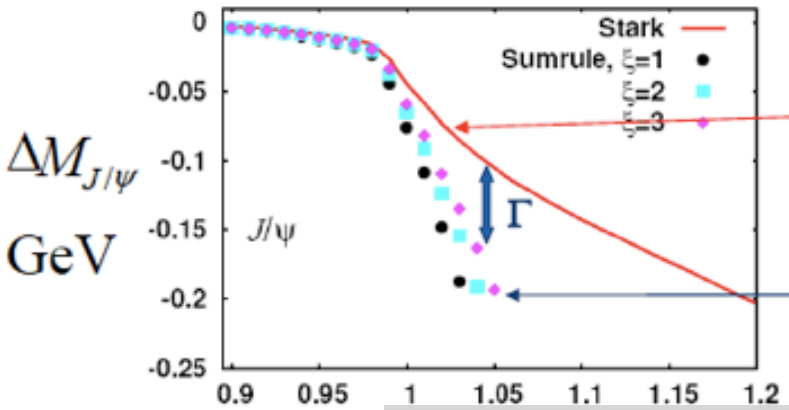
QCD sum-rule approach for quarkonia at finite temperature

Study of heavy quark system very near Tc

Talk by Su Houng Lee

Talk by SH Lee

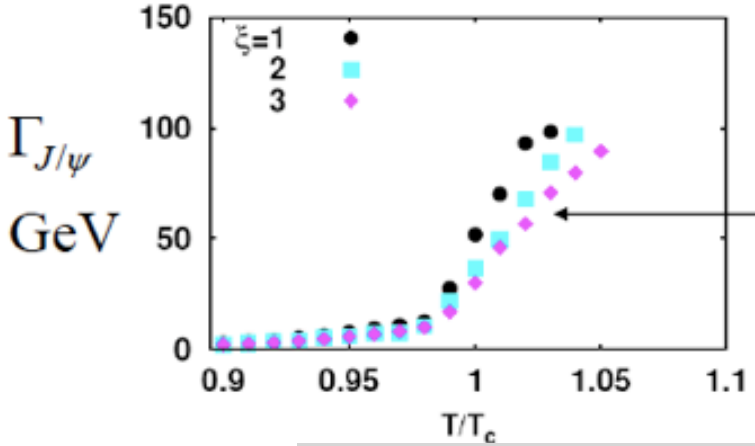
Mass and width of J/ψ near Tc (Morita, Lee 08)



Δm from QCD Stark Effect

QCD sum rule limit with $\Delta\Gamma = 0$

Onset of abrupt mass shift at Tc



Γ =constraint-Δm (Stark effect)

Sudden increase in the width near Tc

S H Lee: 12/17/09 BNL

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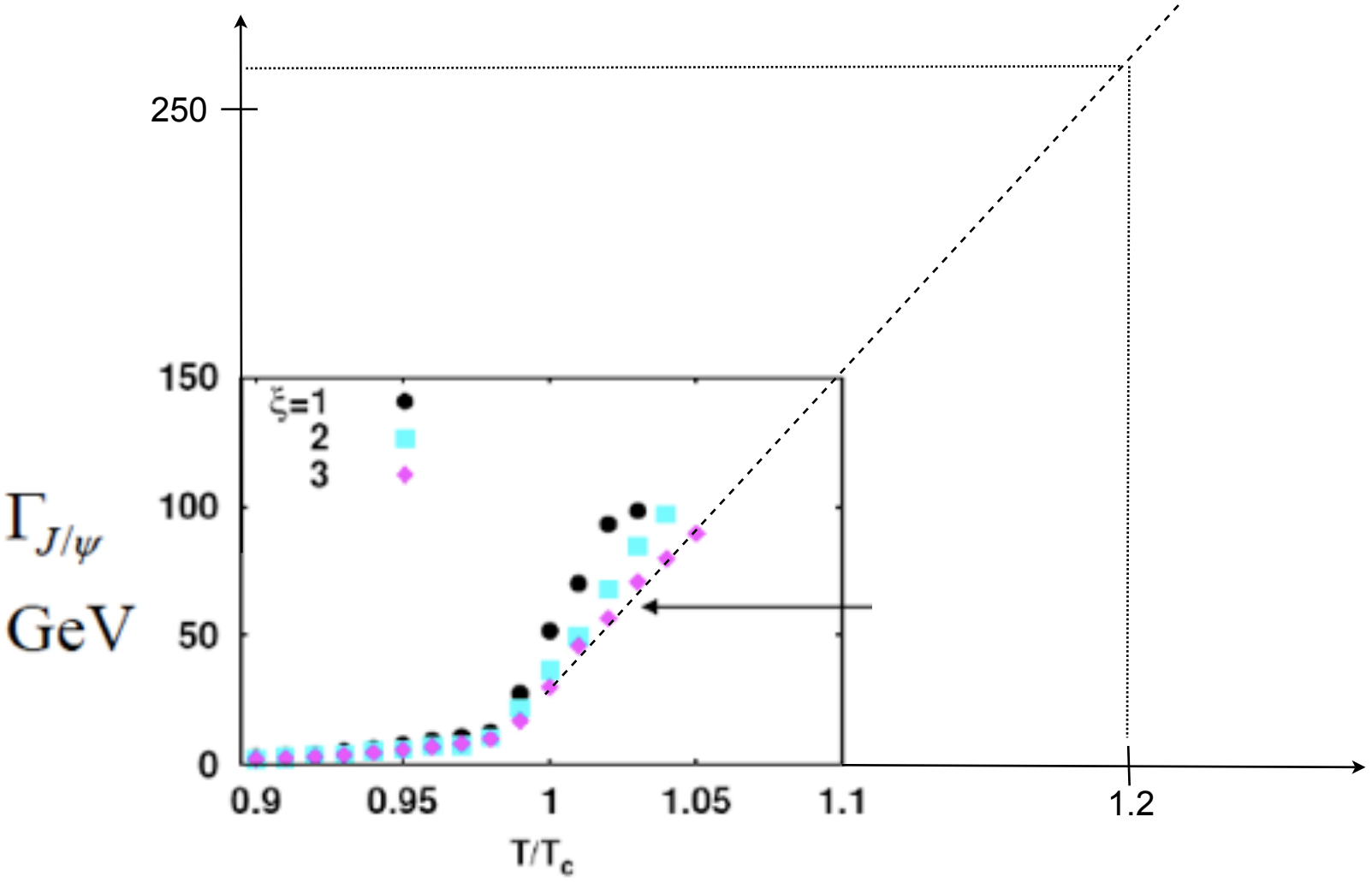
Please allow me, just for fun ...



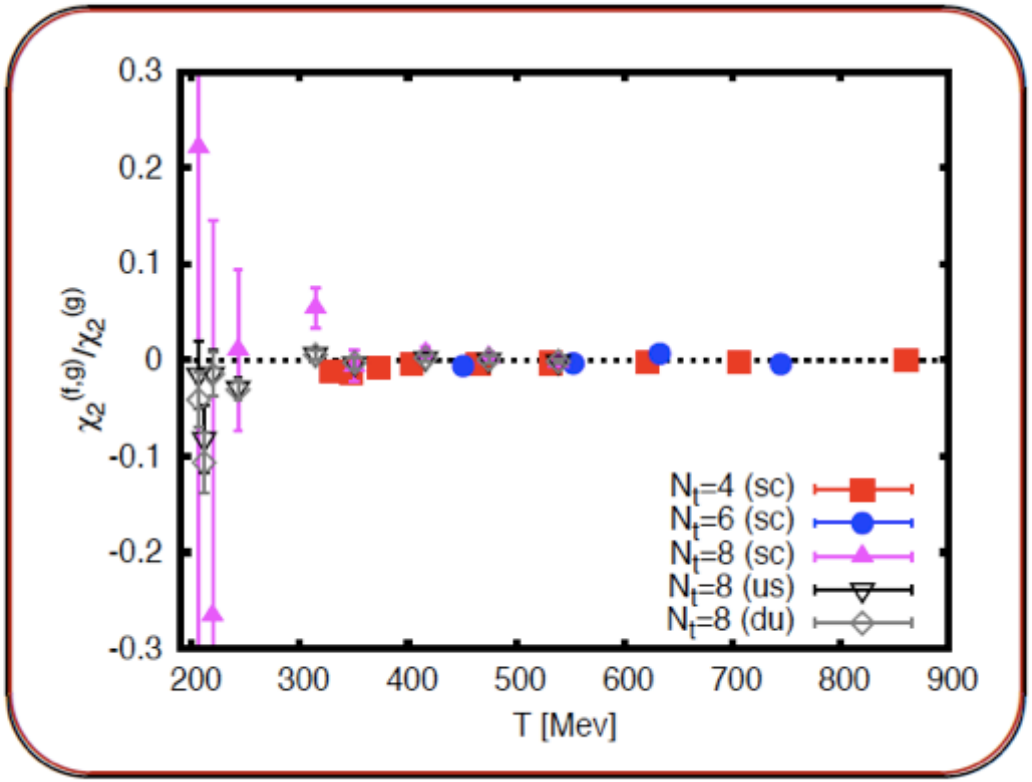
Lattice QCD results for heavy quarks at finite temperature

Heavy quark susceptibilities, correlations

Talk by Swagato Mukherjee

Flavor correlations

$$\chi_2^{(f,g)}/\chi_2^{(g)} = \langle \mathcal{N}_f \mathcal{N}_g \rangle \,/\, \langle \mathcal{N}_g \mathcal{N}_g \rangle$$



Flavor correlations

Talk by S Mukherjee

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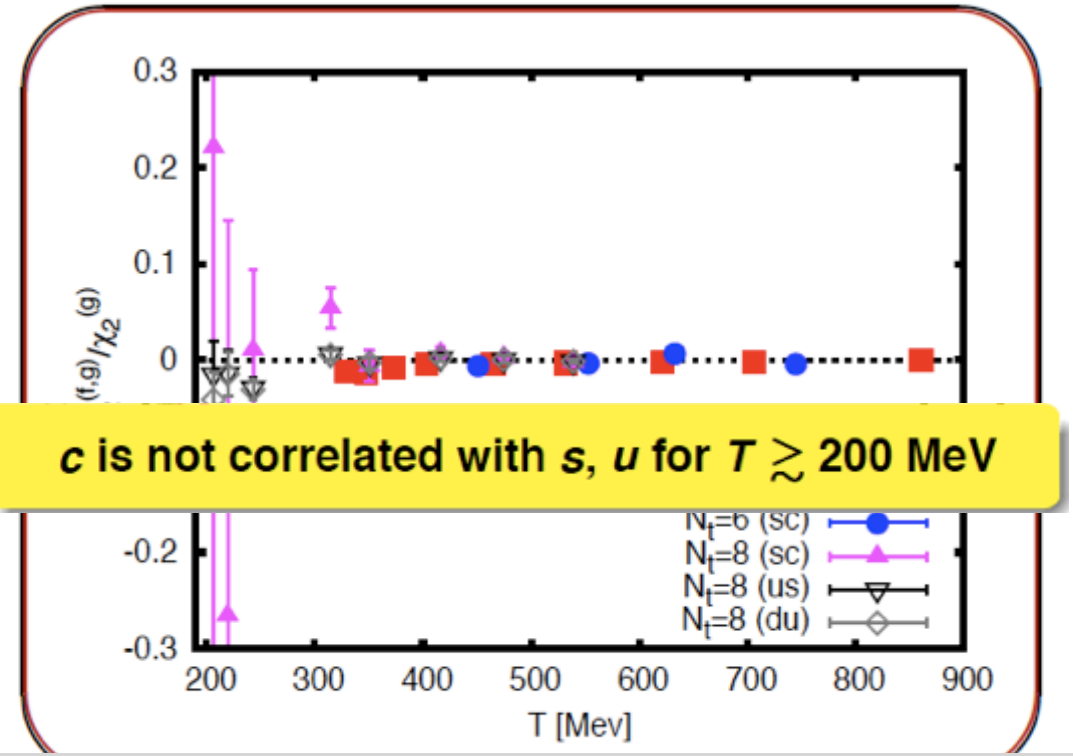


***c* is not correlated with *s*, *u* for $T \gtrsim 200$ MeV**

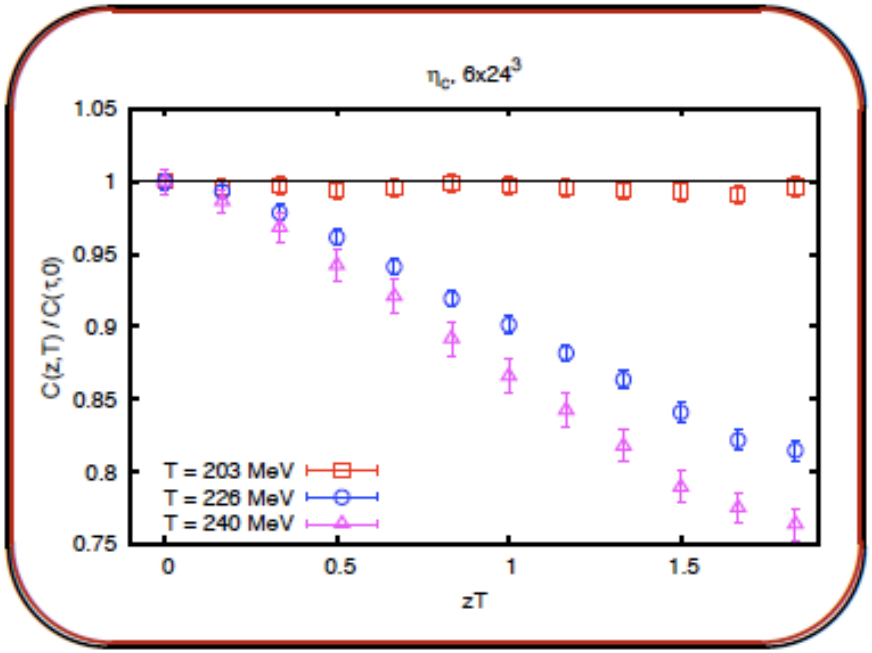
Implies that heavy-light mesons do not exist above Tc

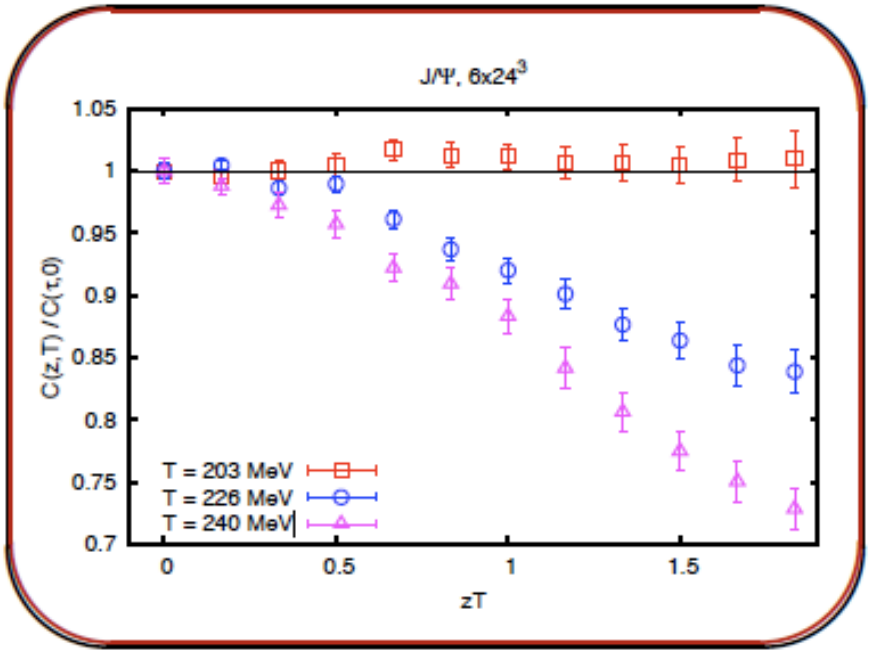
Also: Charm number fluctuations compatible with free quark gas with slightly T-dependent mass

Spatial correlations of charmonia

$$T \to 0 \;:::\; M = m_{had}$$

(Spatial correlator at T)/(Spatial correlator T=0)





Possible indication that there are no quarkonium states

Bridging to experimental data

Through a dynamical model

Talks by Clint Young, Su Houng Lee, Ralf Rapp

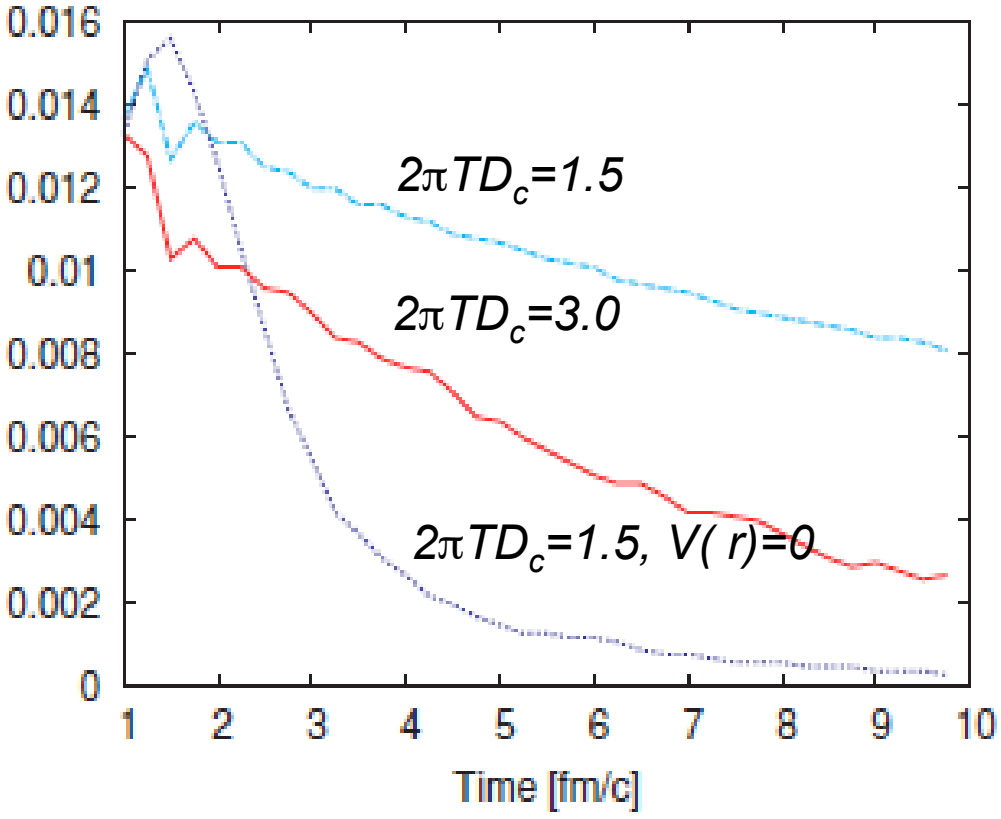
If we take seriously that the Jpsi melts, broadens, not there, ...
why don't we see 100% suppression?

General features of the Langevin-with-interaction model for charmonium

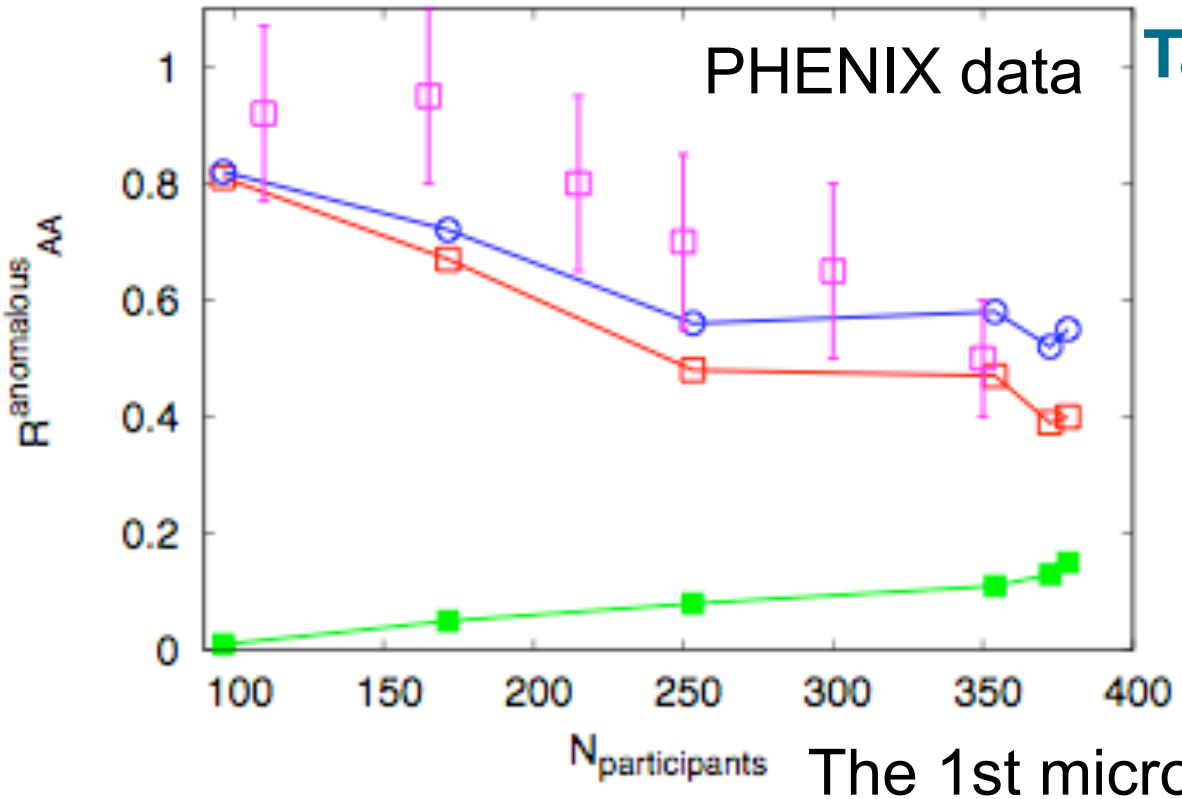
$$\frac{\#\text{ of correlated pairs}}{\text{total \# of c-cbar pairs}}$$

Talk by C Young

- Langevin + hydro (the c-cbar pairs move through the sQGP - drag, Langevin, potential)
- Medium is trying to prevent quarks from being separated
- An ensemble evolving with this large drag coefficient equilibrates rapidly in momentum space, and then experiences slow spatial diffusion.
- Timescales become very important to determine the change in yields of charmonium due to a deconfined phase.



R_{AA} for T_c=190 MeV



Talk by C Young

correlated pairs

The 1st microscopic calculation of non-correlated recombination!

The Langevin-with-interaction model for charmonium in sQGP can explain the suppression pattern for the J/ψ in Au+Au collisions

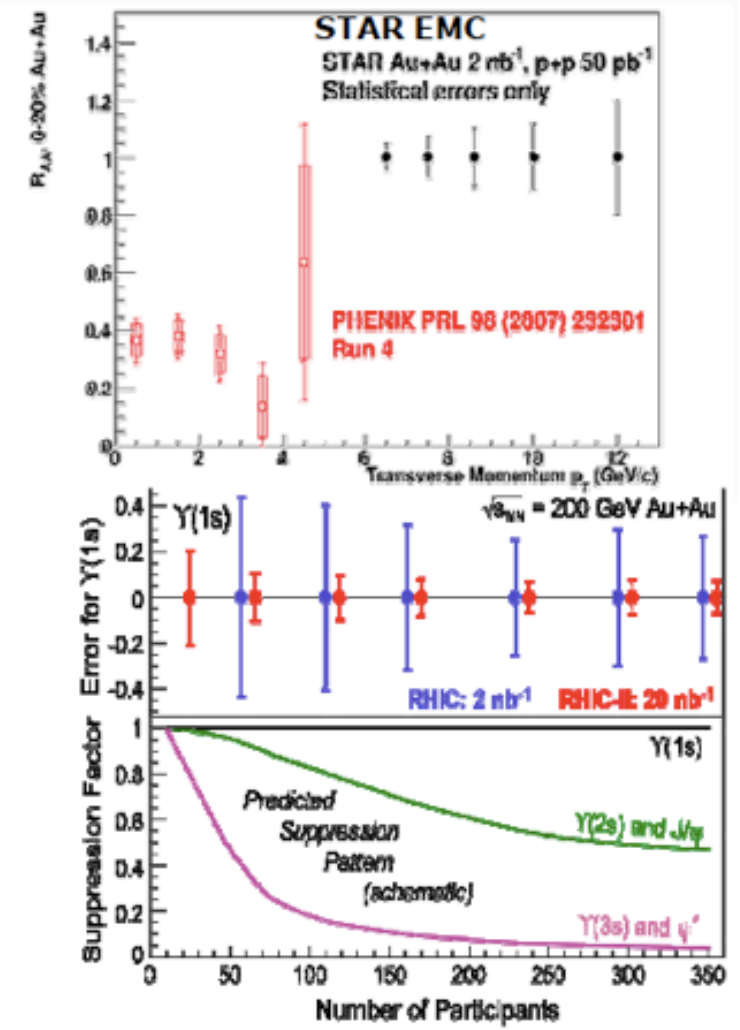
The future is bright

Experimental upgrades in the pipeline

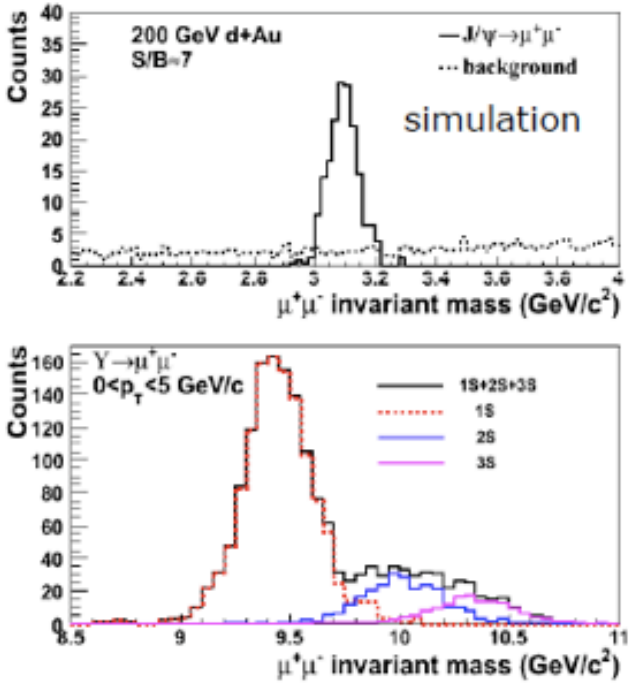
Talk by Zhangbu Xu

The future is bright

High luminosity for Υ & J/ψ



L.Ruan et al., 0904.3774, JPG36(2009);
Z. Xu, BNL LDRD project 07-007
STAR Muon Telescope Detector



MTD: excellent mass resolution for Υ separate different Υ states

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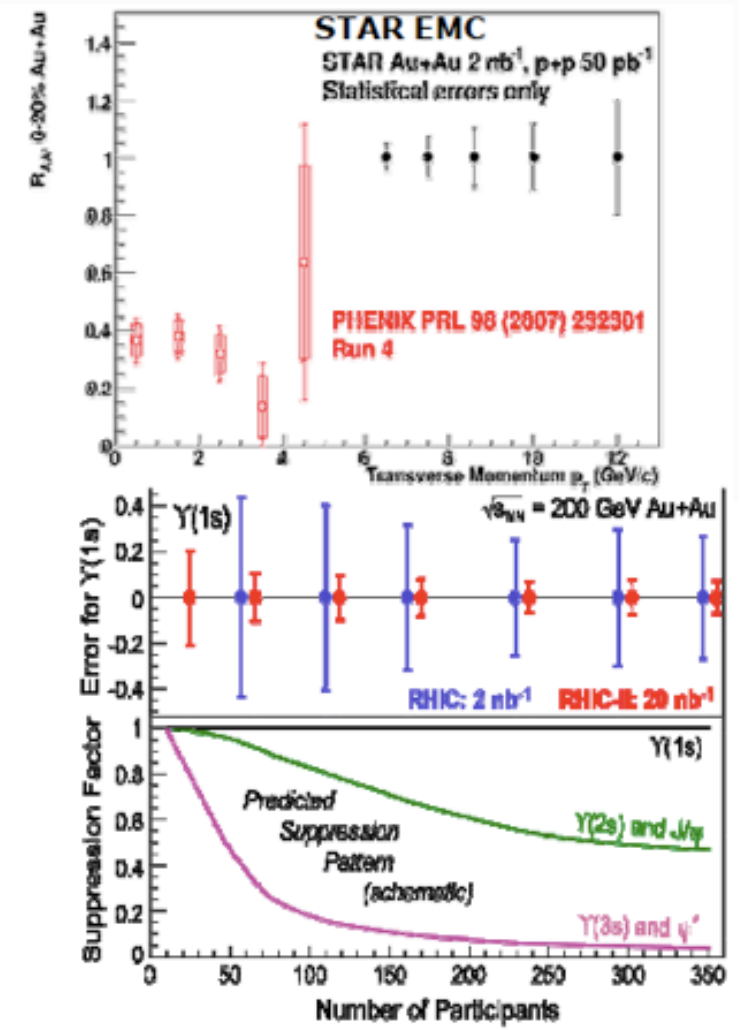
Talk by Z. Xu

The future is bright

High luminosity for Υ & J/ψ



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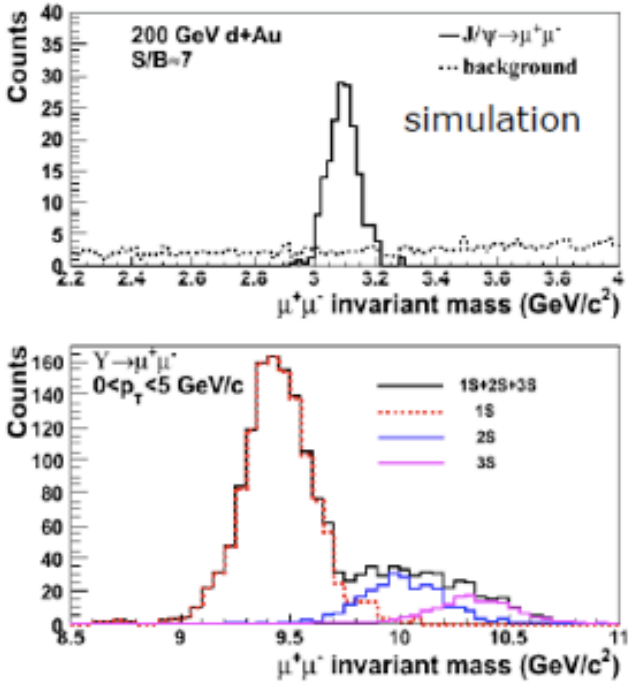
Z. Xu, BNL LDRD project 07-007
STAR Muon Telescope Detector



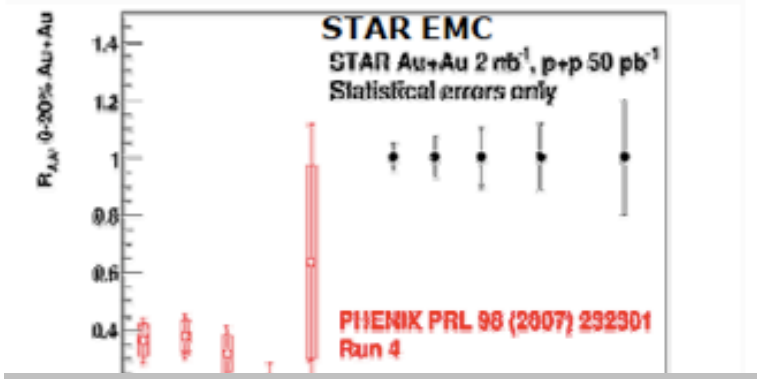
MTD: excellent mass resolution for Υ separate different Υ states

14

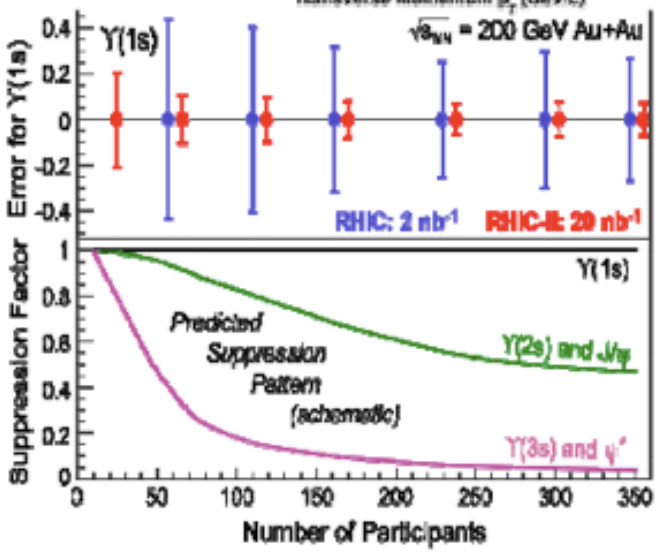
Talk by Z. Xu

The future is bright

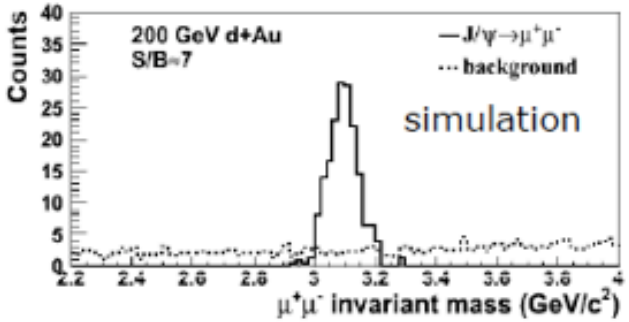
High luminosity for Υ & J/ψ

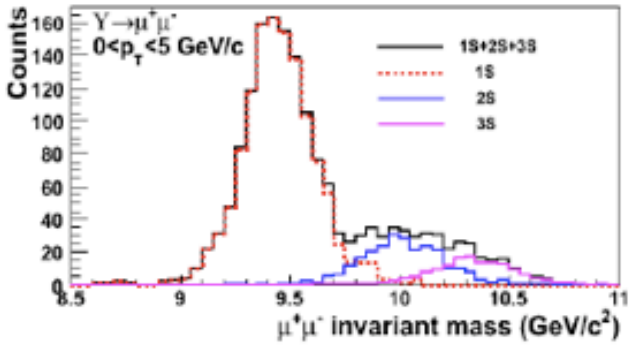


Factor 10 in luminosity



L.Ruan et al., 0904.3774, JPG36(2009);
Z. Xu, BNL LDRD project 07-007
STAR Muon Telescope Detector





MTD: excellent mass resolution for Υ separate different Υ states

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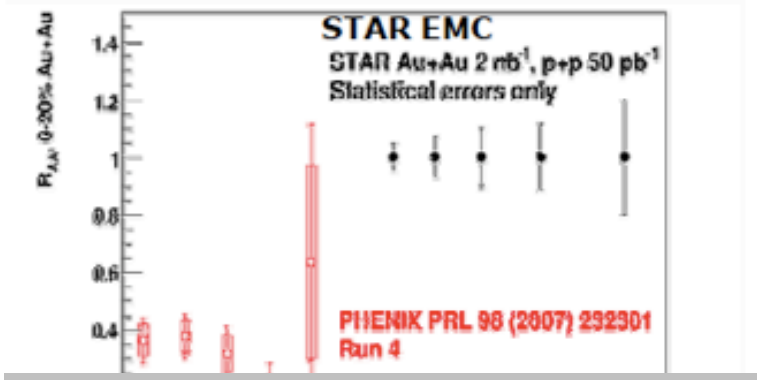
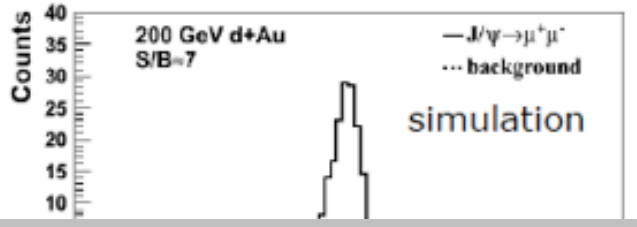
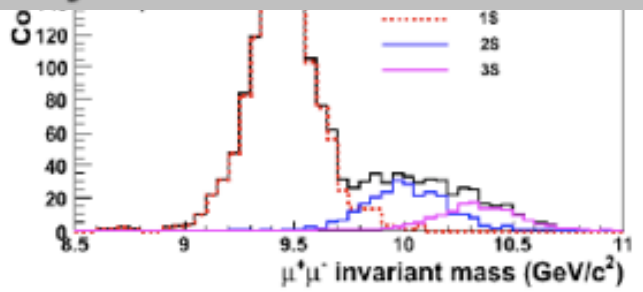


Factor 10 in luminosity

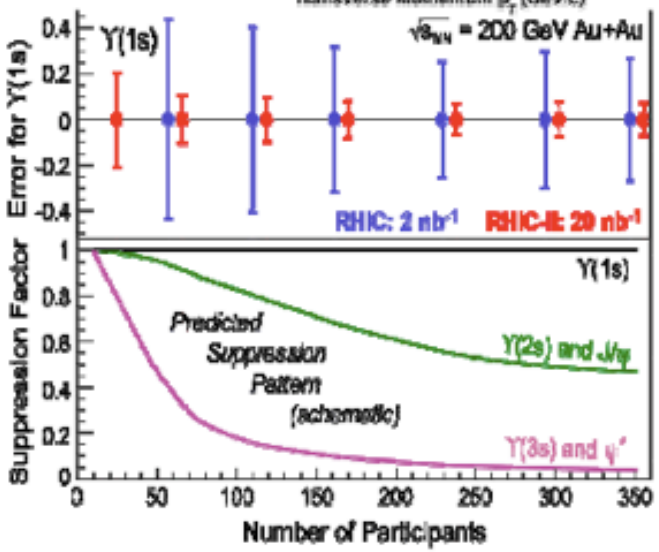
L.Ruan et al., 0904.3774, JPG36(2009);
Z. Xu, BNL LDRD project 07-007
STAR Muon Telescope Detector



Clear ground state peaks
Maybe even excited ones?!



MTD: excellent mass resolution for Υ
separate different Υ states



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THE END